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New England's Underutilized Seafood Species: Defining And Exploring Marketplace Potential In A Changing Climate

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NEW ENGLAND'S UNDERUTILIZED SEAFOOD SPECIES: DEFINING AND EXPLORING MARKETPLACE POTENTIAL IN A CHANGING CLIMATE

A Thesis Presented

by

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ABSTRACT

NEW ENGLAND'S UNDERUTILIZED SEAFOOD SPECIES: DEFINING AND EXPLORING MARKETPLACE POTENTIAL IN A CHANGING CLIMATE

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New England's seafood industry has been searching for opportunities to diversify their landings and build resilience as it faces socio-economic challenges from a changing climate. Developing markets for underutilized species is one way the New England community could help their seafood industry build resilience. This thesis identified New England's underutilized fish species and explored their marketplace potential by examining their availability in a changing climate, current availability to consumers, and consumers' responses. In Chapter I, I account how New England's seafood preferences have changed over time. In Chapter II, I identify New England's seven underutilized seafood species: 1) Acadian redfish *(Sebastes fasciatus)*, 2) Atlantic pollock *(Pollachius virens)*, 3) butterfish *(Peprilus triacanthus)*, 4) the Georges Bank and Georges Bank East stocks of haddock *(Melanogrammus aeglefinus)*, 5) scup *(Stenotomus chrysops* 6) the northern stock of silver hake *(Mercluccius bilinearis)*, and 7) white hake *(Urophycis tenuis)*. In the same chapter, I show that climate change will likely affect the availability of these species differently and that the broader ecological and socio-economic responses from shifting distributions and phenology are largely unknown. In Chapter III, I demonstrate that besides haddock, underutilized species were rarely accessible to consumers in restaurants. In the same chapter, I show how resources would likely help

consumers and restaurants connect with their underutilized species since popular seafood suggestion guides either overlook or provide inconsistent recommendations for all underutilized species. In Chapter IV, I suggest that younger generations (Millennials and Generation Z) are interested in engaging with underutilized species. These younger consumers responded positively to hake, haddock, and Atlantic pollock in sensory assessments. Finally, in Chapter V, I suggest how New England’s seafood supply chain can use results from this research to make more informed policy, marketing, and purchasing decisions that align with their sustainability goals. These insights into availability, access, and consumer response may help New England’s seafood industry strategize approaches that will connect younger consumers to their local seafood options and build new adaptive markets in a changing climate.

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CHAPTER 1

CHANGES IN NEW ENGLAND SEAFOOD

Seafood has always played an integral role in New England's diet, economy, and cultural identity. Changes in fishing technology, trade, marketing, and nature's availability have created distinct socio-economic periods within New England's fishing communities and have shifted seafood preferences over the past few centuries.

Seafood preferences have shifted throughout time. While anadromous species such as herring (*Clupea harengus*) and shad (*Alosa sapidissima*) were staples in the Native American diet, colonists and early Americans chose to dam these fishes' waterways to support power mills. New Englanders then shifted their attention to the open ocean. The salted Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) industry transformed New England's economy in the late 17th century (Murawski 1993; Massachusetts Historical Commission 2014). New England became renowned for building world-class ships and being the backdrop for some of the world's most productive fishing grounds (Murawski 1993; Springuel et al., 2015).

Seafood preferences shifted in part because of more developed fishing technology. Seafood availability expanded beyond Atlantic cod and forage fish like mackerel (*Scomber scombrus*) to large benthic fish like Atlantic halibut (*Hippoglossus hippoglossus*) as fishing technology advanced from hooks and hand-pulled nets to bottom-trawling nets that brought massive demersal fish to the surface for the first time (Grasso 2008; Seaver 2017). Steam power, expansive towed nets, and refrigeration allowed both domestic and international vessels to extract and store an immense amount of fish biomass from the Northwestern Atlantic. Technological advancements in the 19th century changed commercial fishing from an artful skill of finding and pulling fish out of the water by hand, to chasing and scooping large aggregations with nets. During the 19th and 20th century, creative marketing, new cooking methods, and improved transportation transformed several abundantly available species from unappetizing to immensely popular including the American lobster (*Homarus americanus*) and bluefin tuna (*Thunnus thynnus*) (Corson 2004; Grasso 2008; Greenberg 2010).

But fishing pressure by the U.S. and foreign fleets became too intense in the Northwestern Atlantic. Fish populations began collapsing in the 19th and 20th century, including Atlantic halibut and Atlantic cod. New England's fishing economy and eating behavior had to change by the mid-1900s to preserve their fishing heritage for future generations. The presence of farmed and imported seafood increased throughout this time. Now, while many overfished stocks have rebounded, a few, including Atlantic cod stocks, are still considered overfished. However, there are several fish populations that are thriving and abundant but are not being utilized by the fishing industry. It is important to evaluate the marketplace potential of these abundant species since climate change is now creating socio-economic issues for fishermen and the U.S. is primarily consuming imported seafood with high carbon footprints (Pinsky et al. 2009; Pershing et al. 2015; Parker et al. 2018; Shamshak et al. 2019; Young et al 2019; Seafood Carbon Emissions Tool 2020).

In this thesis, I pull together research from various science disciplines to explore and test the marketplace potential of New England's underutilized seafood species. Marketplace potential can be thought of as the likelihood a seafood species can successfully compete for space within restaurants and food markets and be accepted by consumers.

In Chapter II, I define the term "underutilized species" using an original quantitative definition and identify which finfish species managed in New England could be considered underutilized. Then, I synthesize how the primary literature reports on each of these underutilized species in terms of their responses to changing climate conditions to date and their projected responses in the future. In Chapter III, I capture consumers' access to each underutilized species within Boston restaurants in the spirit of the "Eat Local Seafood" movement by conducting two restaurant menu assessments. I also demonstrate the limitations of popular seafood sustainability guides since they often provide inconsistent messages about New England's underutilized species. In Chapter IV, I capture Millennials and Gen-Zers rating perceptions and familiarity towards underutilized species in comparison to a more popular, yet overfished regional species. Finally, in Chapter V, I suggest how my results could help New England's fishing industry advance its sustainability goals in a changing climate. Collectively, results within these chapters may help New England's seafood supply chain strategize approaches that will reconnect consumers to their local seafood options and build new adaptive markets.

CHAPTER 2

IDENTIFYING AND EVALUATING NEW ENGLAND'S UNDERUTILIZED SPECIES IN A CHANGING CLIMATE

2.1 Abstract

Recent events have demonstrated how climate change can disrupt the vitality of New England's seafood. When New England's seafood industries are economically challenged, one successful relief strategy has been diversifying and expanding market opportunities for lesser-known seafood species. Using a new quantitative definition, I identify seven finfish species in New England that are underutilized and could be considered for new market opportunities as part of a climate-smart approach. These seven species are: 1) Acadian redfish *(Sebastes fasciatus)*, 2) Atlantic pollock *(Pollachius virens)*, 3) butterfish *(Peprilus triacanthus)*, 4) haddock *(Melanogrammus aeglefinus)*, 5) scup *(Stenotomus chrysops)*, 6) silver hake *(Mercluccius bilinearis)*, and 7) white hake *(Urophycis tenuis)*. Identifying underutilized species and understanding their responses to a warming climate is a progressive step towards helping New England's seafood industry build more diversified and adaptive markets. By assessing past and future impacts of climate change, communities can collectively anticipate responses from fishes and other marine life, strategize realistic adaptation plans, and implement those plans to create adaptive and resilient fisheries.

2.2 Introduction

2.2.1 Impacts of Climate Change on Fish and Fisheries

The Northwestern Atlantic Ocean is home to some of the most productive and historic fishing grounds in the world, including the Gulf of Maine. The Gulf of Maine is warming faster than 99% of the world's oceans (Pershing et al. 2015), and fish populations are responding to warming temperatures in diverse ways such as shifting abundance, distribution, productivity, and phenology (i.e., seasonal timing of reoccurring life events). Analyses of long-term datasets show that fishes are adjusting their distribution and seasonal occurrence in coastal waters (Nye et al. 2009, Solmundsson et al. 2010; Staudinger et al. 2019) and warming temperatures can drive changes in seasonal occurrences of larval fishes (Walsh et al. 2015), as well as the timing of adult migrations and juvenile emigration events (Ellis and Vokoun 2009; Juanes, Gephard, & Beland, 2004; Otero et al. 2014; Staudinger et al. 2019). While range and phenological shifts demonstrate the ability of these fishes to adapt to changing environmental conditions, these shifts can create detrimental ecosystem-level changes (Weiskopf et al. 2020), including trophic mismatches for food and other resources (Staudinger et al. 2019). At the human dimensions level, phenological shifts in marine species have created financial consequences for fishing communities (Mills et al. 2013) and challenged resource managers (Hudson and Peros 2013). It is important for fishing communities and managers to examine the past, current, and future impacts of climate change so communities can collectively anticipate responses from fishes and other marine life, strategize realistic adaptation plans, and implement those plans to create adaptive and resilient fisheries.

Fishes responses to climate change have created new financial challenges for fishermen. Fishermen's overhead and operational costs increase as they need to travel farther to capture species that shift away from fishing ports (Pinsky et al. 2009; Young et al 2019) into deeper waters or more northern habitats (Nye et al. 2009). Warming waters have also created unstable and less profitable supply and demand relationships for fishing communities (Garcia and Rosenberg 2010; Mills et al 2013). Fishermen are unintentionally catching high-valued species that are moving into the warming region (e.g., emerging species) from southern waters that they are not yet allowed to harvest in substantial numbers or land at regional ports due to current management frameworks (Hudson and Peros 2013). Additionally, small-scale fishers may experience fewer days to safely operate their businesses since climate models predict more frequent and intense storms in the Northeast (Dupigny-Giroux et al. 2018). Currently, fishers receive cents per pound for many species, and financial challenges from climate change are magnified by pricing pressure from increasing amounts of cheaper imported seafood with high carbon footprints (Keithly et al. 2006; NOAA 2011; NOAA 2018; Stoll et al. 2015).

One fishery that suffered immediate financial consequences due to climate change was New England's lobster fishery during summer 2012. During the 2012 heatwave anomaly, sea surface temperatures (SST) in the Gulf of Maine were 1–3°C warmer than the 1982–2011 average. Lobsters moved inshore earlier and increased molting rates in response to early warming temperatures. The surge in supply emphasized weaknesses in New England's seafood transportation and processing infrastructure, ultimately creating a glut of product, and price collapses up to 70% below the expected value (Mills et al. 2013). This single season example highlights how a fishery can be sensitive to quick environmental changes that spark phenological shifts. Recent events demonstrate how the vitality of New England's seafood industries are vulnerable to regulation changes for other marine life (e.g. lobster industry impacted by right whale management decisions) (Bever 2020), changes in international trade relationships (e.g. effects of COVID 19 on seafood exports) (Overton 2020), and the vitality of the hospitality industry (Overton 2020; Wells 2020).When New England's seafood industries are economically challenged, one successful relief strategy has been diversifying and expanding market opportunities for lesser-known seafood items.

2.2.2 Building Resilience With Diversity

New England's seafood industries have a history of creating fresh economic opportunities for lesser-known and low-value marine foods, especially when faced with socio-economic challenges. Lobster in the mid-1800s, and tuna in the early 1900s, are notable local seafood items that were transformed from low-value catch to high-value delicacies with canning technology and creative marketing (Seaver 2017). Squid only recently became a menu favorite in the 1990's, when proper processing infrastructure and advertising was established to encourage consumers to expand their preferences beyond overharvested groundfish populations (Frank 2014; Fishy Thinking 1974). Industry's ability to adapt and diversify markets was also witnessed during the 2012 heatwave anomaly when longfin squid (*Doryteuthis pealeii*), a species primarily caught in Mid-Atlantic states, was present throughout the summer in coastal Maine waters. The region developed a fishery and market opportunities for locally harvested squid within the season to opportunistically take advantage of this emerging species (Frederick, 2012; Mills et al. 2013). Expanded and diversified markets for lesser-known New England seafood species were observed during the COVID-19 pandemic when other animal proteins were difficult to access due to breakdowns in the supply chain. Seafood suppliers and fishers had to pivot their business models away from international markets and large purchasers, towards direct consumer sales (Danderant 2020; Overton 2020; Wells 2020). Selling lesser-known species directly to consumers (Scorese 2019) and through community-supported fisheries (CSFs) are recognized marketplace structures that bolster revenue for fishers (Andreatta 2011; McClenchan et al. 2014, Stoll et al. 2015). History suggests that building successful new markets for lesser-known species is possible with an abundant population, collaboration throughout the chain of custody, and heightened interest from consumers, markets, and restaurants. Moving forward, building new and long-lasting markets will also require that fish populations be consistently accessible in a changing climate.

Here, I identify which finfish species in New England could be considered for new market opportunities as part of a climate-smart approach. First, I created a quantitative definition to define and identify underutilized species. To date, the term "underutilized species" has not been quantified; instead, underutilized species has been described as any regional seafood item that is abundant in the wild but is not well-known or widely used, but has considerable culinary potential (Blank 2018; Whittle 2016; Witkin 2014). Without a quantitative definition, regions are limited in their ability to identify - let alone market - their unique underutilized species as part of the growing "eat local" movement (Brinson et al. 2011; Olson et al. 2014; McClenachan et al. 2014) and as part of a more diversified portfolio of market options (Young et al. 2019)

After identifying New England's underutilized species, I reviewed the primary literature and a recent climate vulnerability assessment (Hare et al. 2016) to assess how underutilized species are responding, and are projected to respond, to changing climate conditions (primarily warming sea surface temperatures and increasing ocean acidity). Identifying underutilized species and understanding their responses to a changing climate is a progressive step towards helping New England's seafood industry build more diversified and adaptive markets. With this climate-smart approach, I provide New England's seafood industry with: 1) a science-based explanation for the term "underutilized'; 2) a list of species that New England's seafood industry can consider for new market opportunities; and 3) a comprehensive science-based overview about how these species have, and may, respond to a changing climate.

2.3 Methods

2.3.1 Identifying Underutilized Species

I used stock assessment and fish monitoring reports from 2013-2017 to assess which finfish stocks managed by the New England Fishery Management Council and Mid-Atlantic Council were underutilized in 2018 using the quantitative definition described below.

A quantitative description should include science-based sustainable fishing metrics from fishing management plans (FMPs) that each region calculates on an annual basis. Metrics include allowable catch limits, cumulative catch (weight kept + weight of discards), fishing status (e.g., overfishing is or is not occurring), and population status (e.g., overfished or not overfished, and at, below, or above target levels). Using these metrics will ensure underutilized fish are characterized consistently across regions. A proposed quantitative definition for underutilized species is any species that: 1) is allowed to be landed, 2) is not overfished, 3) is not experiencing overfishing, 4) has a population at or above target levels, and 5) 50% or less of their annual catch limit (sub-ACL or quota) has been caught in at least three out of the past five years

The stock assessment reports stated the following statuses for each stock: overfished (Yes, No, or Unknown), overfishing (Yes, No, or Unknown), and population level (At, Below or Above Target Level) (NOAA 2018).

The fish monitoring reports detailed whether each species was allowed to be landed, its sub-Annual Catch Limit (ACL) or quota (by season and/or by year), and the annual cumulative catch. For consistency, cumulative catch weights were converted from pounds to metric tons as needed. Data for each species from 2013-2017 was collected from these reports and organized into a database. A list of reports and links to the reports can be found in Supporting Information.

If not already provided in each species' report, *Percent caught* was calculated as:

*Percent caught = (Cumulative Catch / Allowable Catch Limit or Quota) *100*

If the median *Percent caught* over the five-year period (2013 – 2017) for each species was below 50%, then less than 50% of the annual catch limit or quota was used in at least three out of the five years. By using the median percent caught over five years, as opposed to the mean percent caught, annual information cannot collectively be influenced by other years.

2.3.2 Synthesizing Current Life History Knowledge and Climate Change Impacts

Profiles for each species were created based on the primary and grey literature (e.g. government publications and reports) as well as Essential Fish Habitat Source Documents (Cargnelli et al. 1999; Chang et al. 1999; Cross et al. 1999; Pikanowski et al. 1999; Lock et al. 2004; Steimle et al. 1999; Brodziak et al. 2005). Profiles detail life history, management and fishing history, and recent ex-vessel prices.

Results from a recent Vulnerability Assessment (Hare et al. 2016) and related papers were used to assess climate change impacts on each species. In the Vulnerability Assessment, expert reviewers scored each species exposure to climate change, the sensitivity of biological traits that are indicative of an ability or inability for the species to respond to environmental change (e.g. sensitivity attributes), the overall directional effect climate change is expected to have on the species, un/certainty in the scores, and the quality of data available to the expert reviewers.

2.4 Results

2.4.1. Identifying Underutilized Species

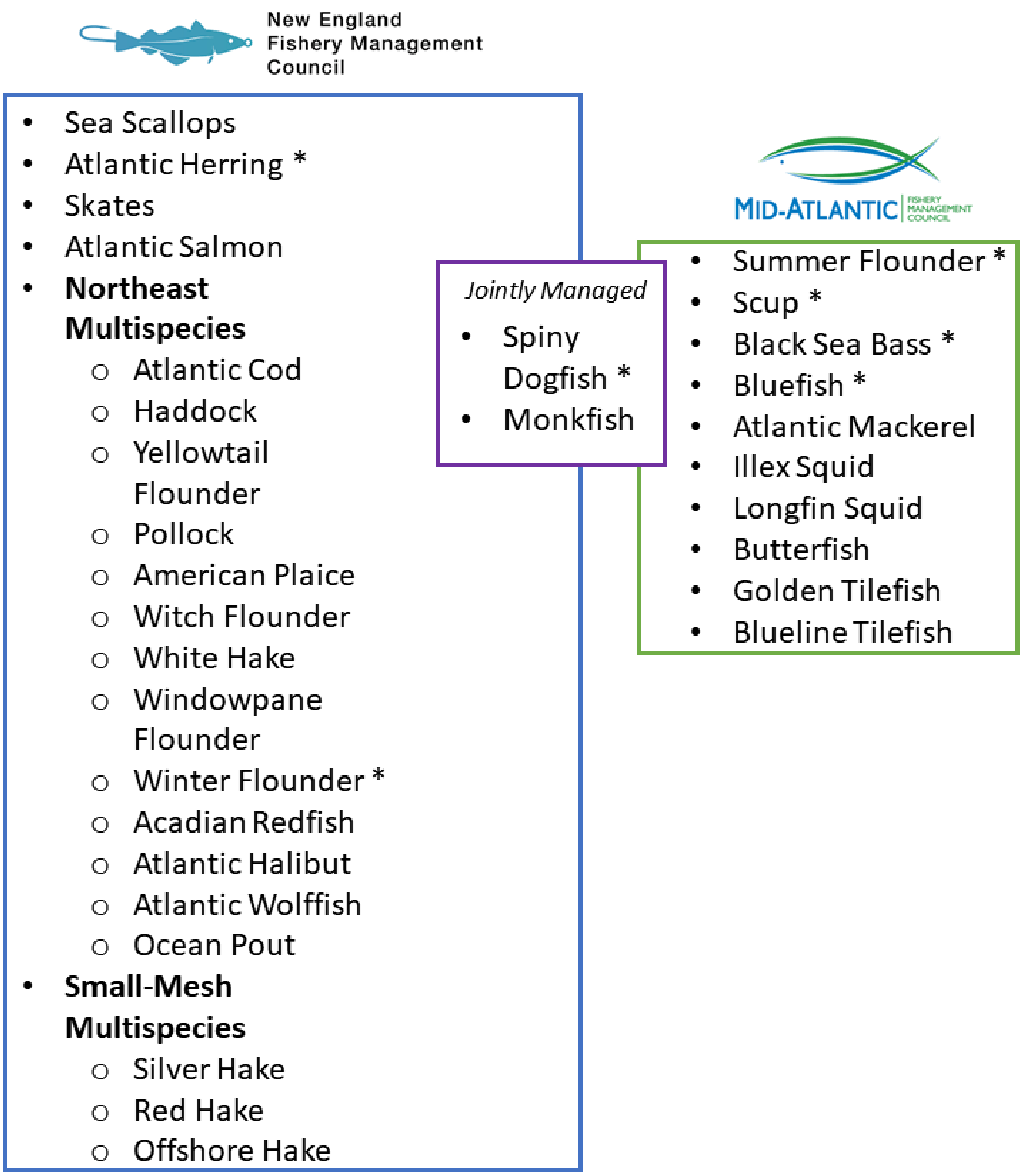


Figure 2.1: A list of all fish species managed by the New England Fishery Management Council and the Mid-Atlantic Fishery Management Council.
Management responsibilities are also shared with the Atlantic States Marine Fisheries Commission for fish marked with an asterisk (*).

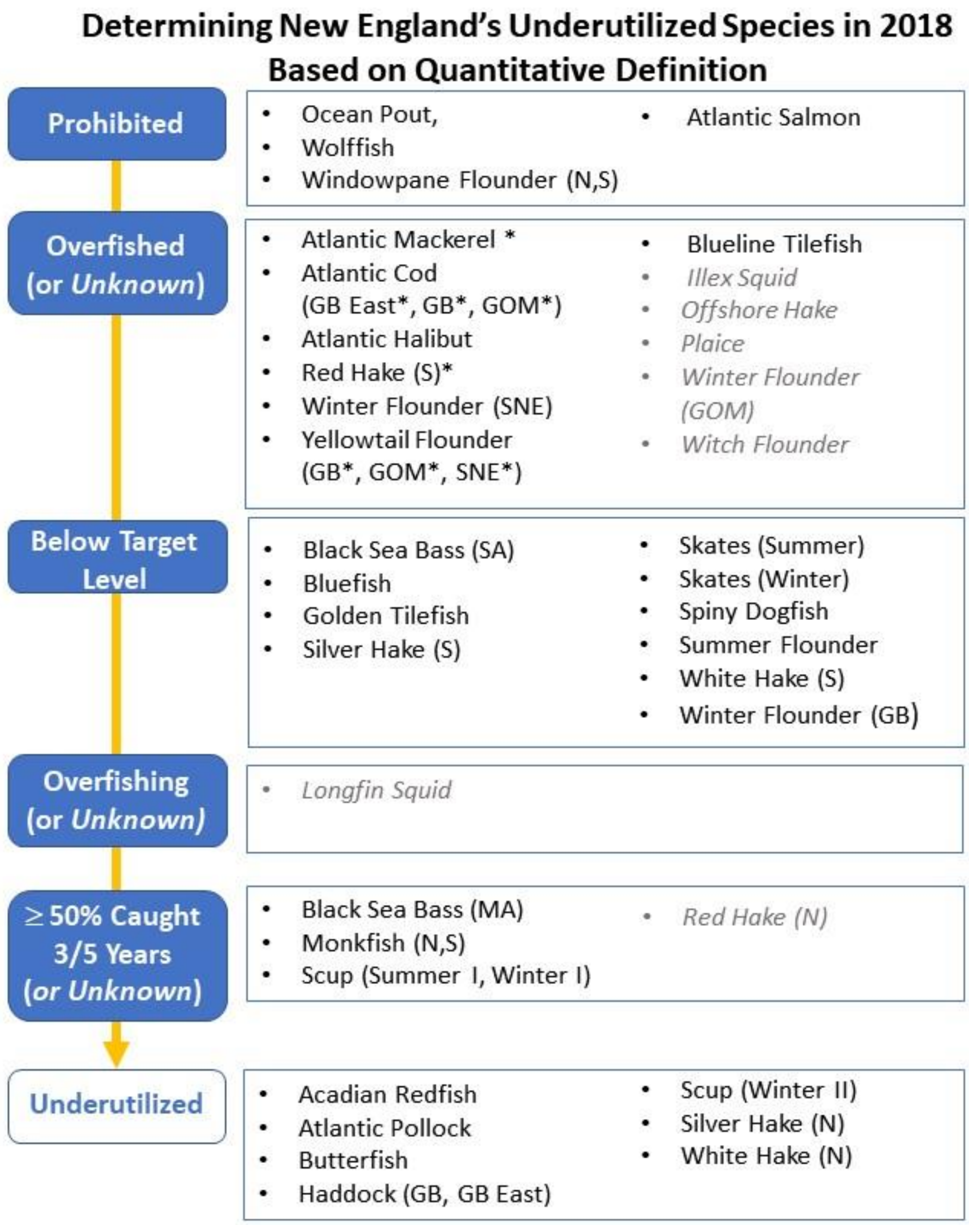


Figure 2.2: Assessing eligibility to be an underutilized species. A flowchart showing how each fish stock was assessed for eligibility as an underutilized species according to the proposed quantitative definition. Stocks italicized in grey indicate they were ineligible from further evaluation because their status for the given metric was unknown. Statuses were unknown either because the management organization did not have enough information to decide or the data available was insufficient (northern red hake). An asterisk (*) identifies stocks that were considered overfished and overfishing occurred. Abbreviations for stocks include northern (N), southern (S), Mid-Atlantic (MA), Southern Atlantic (SA), Georges Bank (GB), Georges Bank East (GBE), Gulf of Maine (GOM), and southern New England (SNE).

	Species	Prohibited?	Overfished?	Target Levels	Overfishing?	50%+ Remaining
Underutilized	Butterfish	No	No	above	No	Yes
	Haddock (GB East)	No	No	above	No	Yes
	Haddock (GB)	No	No	above	No	Yes
	Pollock	No	No	above	No	Yes
	Redfish	No	No	above	No	Yes
	Scup (WinterII)	No	No	above	No	Yes
	White Hake (Northern)	No	No	above	No	Yes
	Silver Hake (Northern)	No	No	above	No	Yes
≥ 50% Caught 3/5 Years	Black Sea Bass (MA)	No	No	above	No	No
	Haddock (GOM)	No	No	above	No	No
	Monkfish (North)	No	No	above	No	No
	Monkfish (South)	No	No	above	No	No
	Scup (Summer)	No	No	above	No	No
	Scup(Winter I)	No	No	above	No	No
Below Target	Silver Hake (Southern)	No	No	below	No	Yes
	White Hake (Southern)	No	No	below	No	Yes
	Winter Flounder (GB)	No	No	below	No	Yes
	Golden Tilefish	No	No	below	No	Yes
	Spiny Dogfish	No	No	below	No	Yes
More Than 1 Metric	Black Sea Bass (SA)	No	No	below	No	No
	Bluefish	No	No	below	No	No
	Skates (Summer)	No	No	below	No	No
	Skates (Winter)	No	No	below	No	No
	Summer Flounder	No	No	below	Yes	No
	Halibut	No	Yes	below	No	No
	Winter Flounder (SNE)	No	Yes	below	No	No
	Atlantic Mackerel	No	Yes	below	Yes	Yes
	Cod (GB East)	No	Yes	below	Yes	Yes
	Yellowtail Flounder (GB)	No	Yes	below	Yes	Yes
	Yellowtail Flounder (SNE/MA)	No	Yes	below	Yes	Yes
	Cod (GB)	No	Yes	below	Yes	No
	Cod (GOM)	No	Yes	below	Yes	No
	Yellowtail Flounder (GOM)	No	Yes	below	Yes	No
	Red Hake (southern)	No	Yes	below	Yes	NA
Prohibited	Windowpane (Northern)	Yes	NA	below	NA	No
	Windowpane (Southern)	Yes	NA	below	NA	No
	Ocean Pout	Yes	NA	NA	NA	Yes
	Atlantic Salmon	Yes	Yes	below	NA	NA
	Wolffish	Yes	Yes	NA	Yes	Yes
Unavailable Data	Illex Squid	No	NA	NA	NA	Yes
	Plaice	No	NA	NA	NA	No
	Witch Flounder	No	NA	NA	NA	No
	Offshore Hake	No	NA	NA	NA	NA
	Winter Flounder (GOM)	No	NA	NA	No	Yes
	Longfin Squid	No	No	above	NA	No
	Blueline Tilefish	No	Yes	NA	No	NA
	Red Hake (Northern)	No	No	above	No	NA

Table 2.1: Status of each metric used to evaluate underutilized species. An organized list of the status of each metric used to evaluate if a fish stock can be considered underutilized. Fish stocks highlighted in green fulfilled all criteria for being underutilized because they 1) are allowed to be landed 2) have populations above target level, 3) are not overfished, 4) overfishing is not occurring, and 5) more than 50% of the quota/allowable catch has remained in at least 3 out of 5 years from 2013-2017. The left column identifies why the stock did not fulfill the criteria to be an underutilized species. Abbreviations for stocks include Mid-Atlantic (MA), Southern Atlantic (SA), Georges Bank (GB), Georges Bank East (GBE), Gulf of Maine (GOM), southern New England (SNE), and Not Available (NA)

In 2018, seven species (eight stocks out of 47 fish stocks) were underutilized in the Northeastern U.S. under the proposed quantitative definition: 1) Acadian redfish

(Sebastes fasciatus), 2) Atlantic pollock *(Pollachius virens)*, 3) butterfish *(Peprilus triacanthus)*, 4) the Georges Bank and Georges Bank East stocks of haddock *(Melanogrammus aeglefinus)*, 5) scup *(Stenotomus chrysops* (only during Winter II season), 6) the northern stock of silver hake *(Mercluccius bilinearis)*, and 7) white hake *(Urophycis tenuis)* (Table 2.1). Two underutilized stocks are managed by the Mid-Atlantic Fishery Management Council and six are managed by the New England Fishery Management Council (Figure 2.1). Species profiles can be found in Supplemental Information Appendix.

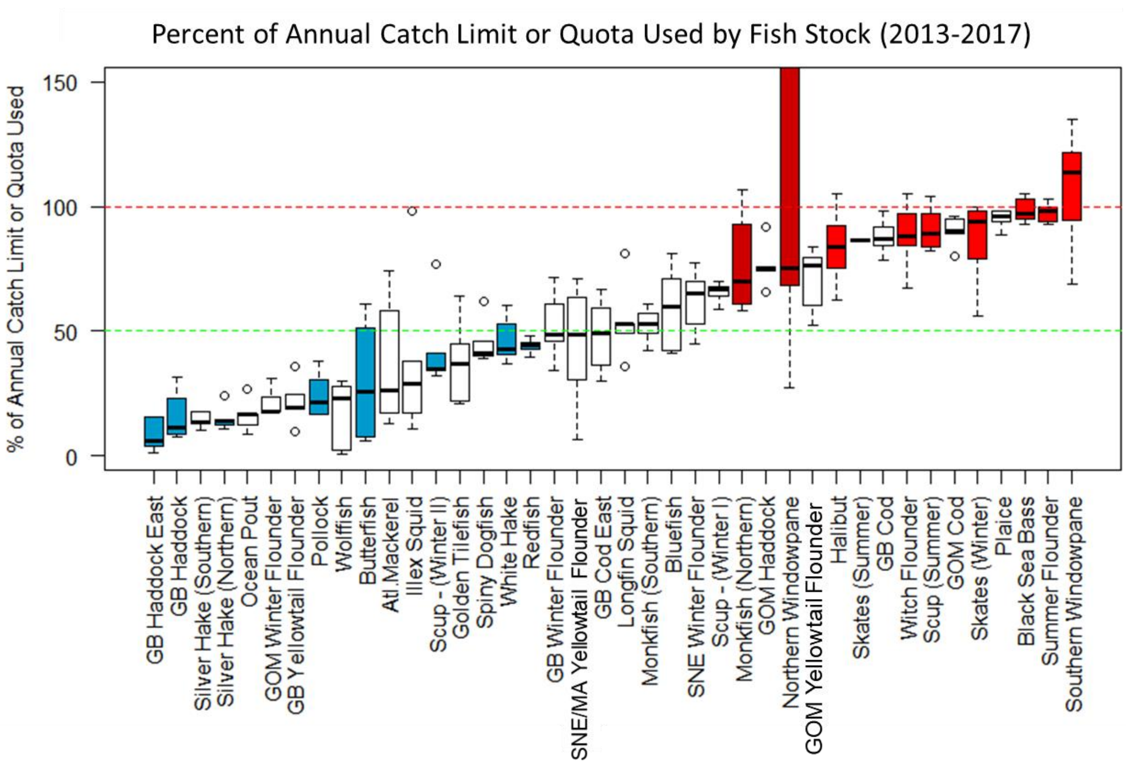


Figure 2.3: Boxplots showing percent of annual catch limit (ACL) or quota used from 2013-2017 for stocks managed by the New England Fishery Management Council and the Mid Atlantic Fishery Management Council. Stocks in blue are underutilized under the proposed definition. Red plots highlight which stocks exceeded their ACL at a time between 2013-2017. The green dash line marks 50% of the ACL or quota and the red dash line marks 100% of the ACL or quota. Fish stock abbreviations include Georges Bank (GB), Georges Bank East (GB East), Gulf of Maine (GOM), Southern New England (SNE), and Mid-Atlantic (MA).

2.4.2 Vulnerability to Climate Change

			Underutilized Species						
Results from Vulnerability Assessment			Scup	White Hake	Acadian Redfish	Atlantic Pollock	Butterfish	Silver Hake	Haddock
		Overall Vulnerability Ranking							
		Climate Exposure							
	Exposure Factors	**Sea Surface Temperature**	4	3.9	3.9	3.9	4	3.9	3.9
		Ocean Acidification	4	4	4	4	4	4	4
		Air Temperature	4						
		Biological Sensitivity							
	Sensitive Biological Attributes	**Population Growth Rate**	2.5	2.6	3.5	3			
		Spawning Cycle	3.2	2.7	2.6				
		Early Life Requirements	2.5			2.6			
		Stock Status		2.6					
		Adult Mobility			2.8				
		Vulnerability to Distribution Shift							
		Certainty of Distribution Shift	100%	100%	97%	98%	52%	100%	73%
		Directional Effect	Positive	Negative	Negative	Negative	Positive	Negative	Negative
		Certainty of Directional Effect	uncertain, <66%	certain, 90 - 95%	certain, >95%	certain, >95%	certain, >95%	certain, >95%	uncertain, 66-90%
		Data Quality	88%, moderate	79%, moderate	88%, moderate	88%, moderate	83%, moderate	88%, moderate	88%, moderate
		Key:	Low	Moderate	High	Very High			

Table 2.2: Results from the vulnerability assessment for each underutilized species. Exposure factors and sensitivity attributes that received a mean score ≥ 2.5 (max of 4.0) are shown. Scores for un/certainty of distribution shift are based on results from a bootstrap analysis. Scores for un/certainty of directional effect and data quality are based on responses from expert reviewers. Species-specific information adopted from S7 Supporting Information – Species Narratives from Hare et al. (2016).

All underutilized species were found to have very high exposure to two impacts of concern: increasing sea surface temperature and more acidic ocean conditions. Warmer air temperature was an additional impact of concern for scup since they school close to the surface and use shallow coastal habitats (Table 2.2).

Butterfish, silver hake, and haddock received a low overall biological sensitivity score and no sensitivity attributes received a mean score ≥ 2.5 out of 4.

Scup also received a low overall biological sensitivity score. However, the three sensitivity attributes received a mean score ≥ 2.5: population growth rate, spawning cycle, and early life requirements. Scup received these scores because their eggs hatch quickly after 2-4 days and grow slowly throughout the larval and juvenile phase when they require inshore coastal and estuarine habitat (Table 2.2).

White hake, Acadian redfish and Atlantic pollock received moderate biological sensitivity scores and two or more sensitivity attributes had a mean score ≥ 2.5. These species were viewed as more biologically sensitive to climate change because of their population growth rates, spawning cycles, early life requirements, stock status, and/or adult mobility.

All underutilized species received high or very high scores for vulnerability to distribution shifts. However, bootstrap analysis shows less certainty about the scores for butterfish and haddock. Only scup and butterfish are expected to benefit from climate change (e.g. positive directional effect) while the other species are expected to be challenged by climate change (e.g. negative directional effect). Reviewers expressed uncertainty about the directional effect of both scup and haddock (Table 2.2).

2.4.3 Observed and Projected Shifts in Distribution and Abundance

The seven underutilized fish species span diverse distributions, phenologies, and responses to climate change. Scientists used long-term environmental datasets to assess how underutilized species responded, and are projected to respond, to changing climate conditions. Nye et al. (2009) reported significant shifts in centers of stock biomass and spatial use in several underutilized species from 1968-2007. Henderson et al. (2017) reported significant correlations between the stock biomass or centers of stock biomasses, and earlier timing of spring (e.g. early onset spring phenology) or longer summer duration. Scientists have made end of the century species-specific projections about centroid shifts, changes in thermal habitat availability (Morely et al. 2018), and seasonal changes in thermal habitat area (Kleisner et al. 2017). Morley et al. (2018) projected future suitable thermal habitat availability and centroid shifts using Representative Concentration Pathway (RCP) scenarios where RCP 2.6 represented a low future greenhouse gas emissions scenario, where warming is limited to 2°C by the end of the century, and RCP 8.5 represented a high “business as usual” future greenhouse gas emissions scenario. The centroids of most species were projected to shift northwards with greater northward shifts projected under RCP 8.5 (Figure 2.6). Kleisner et al. (2017) used a high-resolution climate model (CM 2.6) to calculate seasonal changes in suitable habitat thermal area. Thermal area was described as the area that a species could potentially occupy given appropriate temperature, depth, and bathymetric conditions. End of the century climate simulations in CM 2.6 roughly reflect the climate response of RCP 8.5 in years 2060-2080.

Acadian Redfish

Acadian redfish are temperature sensitive and will likely be negatively affected by climate change (Hare et al. 2016). From 1968-2007, Acadian redfish reduced the area they occupy by approximately 2,400 square miles (159.8 km2 yr–1) (Nye et al. 2009). Their fall stock biomass appeared to be influenced by summer duration (Henderson et al. 2017). By the end of the century under RCP 8.5, Acadian redfish are projected to have the largest northward centroid shift relative to the other six underutilized species (over 800 km) and lose almost half of their historic suitable thermal habitat (Morley et al. 2018) (Figure 2.5-Figure2.6). Under CM 2.6, Acadian redfish are projected have a lose a greater percentage of thermal area in the fall (-35%) than in the spring (Kleisner et al. 2017) (Figure 2.4).

Atlantic Pollock

Atlantic pollock are expected to be challenged by climate change, particularly through changes in their distribution, population growth rate, and early life requirements (Hare et al. 2016). Atlantic pollock reduced the area they historically occupied by 281.1

km2 yr–1 between 1968-2007 and have moved into deeper waters (1.36m yr–1) (Nye et al. 2009). Thermal habitat projections for Atlantic pollock could not be sufficiently made at the seasonal level (Kleisner et al. 2017) and it is unclear whether they will gain or lose overall suitable thermal habitat area under either RCP scenario (Morely et al. 2018).

Butterfish

Butterfish are expected to benefit from warming climate conditions (Hare et al. 2016). Butterfish were not evaluated by Nye et al. (2009), but an analysis from Collie et al. (2008) captured an increase in species with higher temperature preferences, including butterfish, in Narragansett Bay between 1959-2005 when it warmed 1.6°C. Butterfish were projected to gain a significant amount of suitable thermal area in both the spring (306%) and fall (24%) seasons under CM 2.6 (Kleisner et al. 2017). Butterfish are expected to shift northward throughout the rest of the century and gain a significant percentage of suitable thermal habitat under both RCP scenarios (Morley et al. 2018).

Haddock (GB and GBE)

While haddock received a ‘low’ biological sensitivity score, they are expected to be negatively affected by climate change (Hare et al. 2016). Haddock in Georges Bank have significantly constricted the areas they occupy over recent decades (Nye et al. 2009). The timing and duration of seasons appear to impact the northern haddock population. Earlier springs may negatively impact haddock recruitment and are related to the center of northern haddock biomass shifting further north. Meanwhile, longer summers may positively affect fall stock biomass with a 2-year lag (Henderson et al. 2017). By the end of the century under CM 2.6, thermal area for haddock is projected to decline in the spring (-19%) and fall (-46%) (Kleisner et al. 2017). Haddock are projected to shift northward under both RCP scenarios. Suitable thermal habitat for haddock was projected to increase by 3.5% under RCP 2.6 and decrease by 26% under RCP 8.5. (Morley et al. 2018).

Scup

Scup are expected to benefit from warming climate conditions. Scup were not evaluated by Nye et al. (2009) but results from Bell et al. (2015) suggest from 1972-2008 the along-shelf center of biomass of scup during spring had a significant positive relationship with temperature. Also, the suitable thermal habitat for scup shifted northward and larger scup were found further north than smaller scup during spring (Bell et al. 2015). Scup also became more abundant in Narragansett Bay between 1959-2005 when it warmed 1.6°C (Collie et al. 2008). Scup are projected to gain thermal area in both spring (128%) and fall (48%) (Kleisner et al. 2017). Their suitable thermal habitat is expected to continue expanding northward throughout the rest of the century (Morley et al. 2018).

Silver Hake

Both silver hake stocks made significant poleward shifts (Nye et al. 2009). Northern silver hake significantly expanded the areas they occupy while southern silver hake significantly constricted the areas they occupy and have moved into shallower waters (Nye et al. 2009). Earlier spring timing may negatively affect early life stages of silver hake - there was a negative correlation between 1-year lag spring stock biomass of silver hake and spring phenology. Northern silver hake distributions appear slightly more northward in years with extreme rates of early warming (Henderson et al. 2017). Silver hake shifted out of Narragansett Bay over time as water temperatures increased 1.6°C

(Collie et al. 2008). Both silver hake stocks are expected to gain thermal habitat area in the spring but lose suitable habitat area in the fall under CM 2.6 (Kleisner et al. 2017). It is unclear whether they will gain or lose overall suitable thermal habitat area under both RCP scenarios (Morely et al. 2018).

White Hake

White hake made significant poleward movements, significantly expanded the area that they occupy, and moved into significantly deeper waters (Nye et al. 2009). Longer summer duration may negatively affect early life stages of white hake - fall stock biomass indicated a 4-year lag negative response to summer duration (Henderson et al. 2017). Thermal area is not expected to drastically change for silver hake in either season under CM 2.6 (Kleisner et al. 2017). White hake are expected to gain a small percentage of thermal habitat area under both RCP scenarios (Morley et al. 2018).

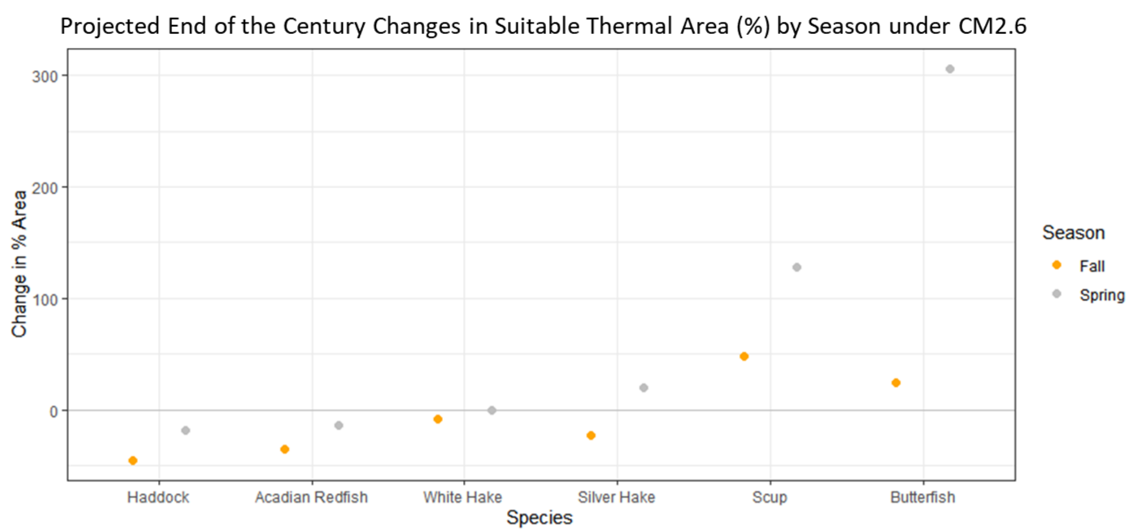


Figure 2.4: Changes in thermal area for underutilized species under CM 2.6.
End of the century projection of seasonal changes in thermal area (by percentage) for underutilized species under CM 2.6. Results below zero indicate a projected loss in percent of suitable thermal habitat while results above zero indicate projected gain in percent of suitable thermal habitat. Projections could not be made for Atlantic pollock. Butterfish and scup are projected to gain the most thermal habitat (by percentage) Data adopted from Supplementary Material from Kleisner et al. (2017).

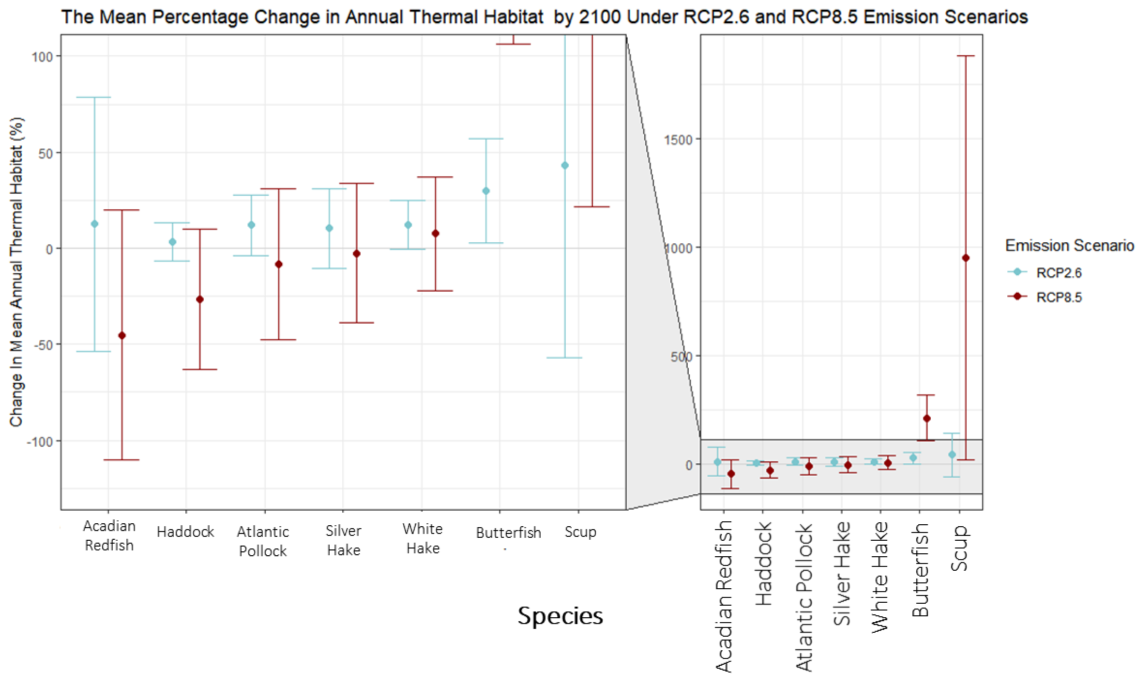


Figure 2.5: Projected change in annual suitable thermal habitat. Projections of mean percentage change and standard error in annual suitable thermal habitat for all underutilized species under different greenhouse gas concentration scenarios by 2100. Mean percent changes in annual thermal habitat differ greatly by scenario and by species. Butterfish and scup are projected to gain the most thermal habitat (by percentage) but also have the most uncertainty in extent. Bars display reported standard deviation. Data adopted from Morley et al. (2018)

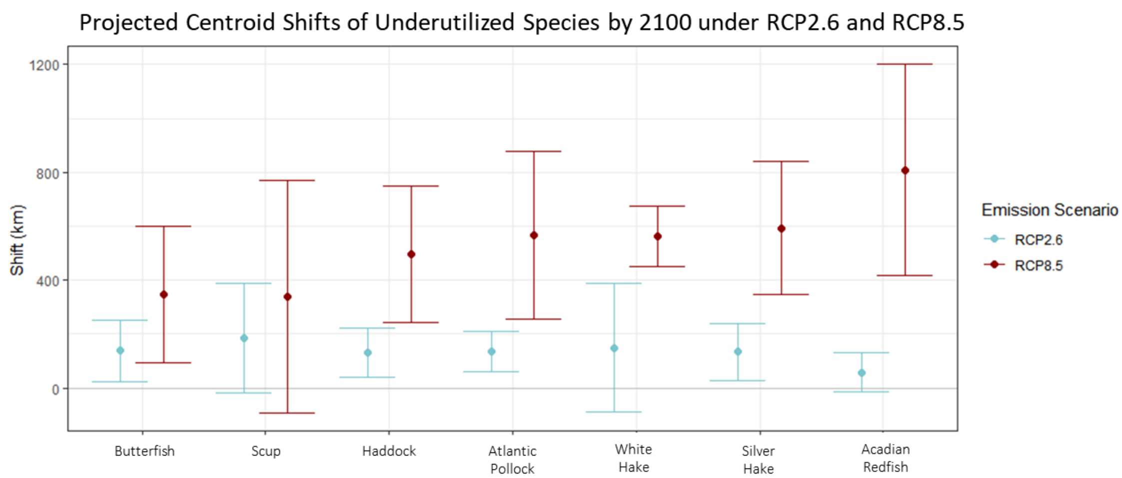


Figure 2.6: Projected shifts by 2100. Projections of centroid shifts (km) and standard error for all underutilized species under different greenhouse gas concentration scenarios by 2100. Projected shifts differ greatly by scenario and by species. Acadian redfish are projected to make the largest shift under an RCP8.5 scenario. Bars display reported standard deviation. Data adopted from Morley et al. (2018)

2.5 Discussion

Applications and Limitations of Definition

The proposed definition and approach for identifying underutilized species allows regional managers to regularly assess their fish stocks on an annual basis with metrics they already use or are familiar with. This approach can also show which species could be considered underutilized with management assistance. For example, spiny dogfish (*Squalus acanthias*), golden tilefish (*Lopholatilus chamaeleonticeps*), silver hake (northern), white hake (southern), and winter flounder (*Pseudopleuronectes americanus*) (Georges Bank) fulfill all criteria to be an underutilized species except they are slightly below their target levels (Table 2.1). These species of interest may benefit from policies that improve population levels and could be revisited for future evaluations. At the same time, this definition allows managers to see which fish stocks are both well utilized and meeting management goals. Fish stocks in 2018 that were not overfished, not experiencing overfishing, and had more than 50% of the ACL/quota used, but did not exceed 100% of quota/ACL from 2013-2017, were haddock (Gulf of Maine), monkfish (*Lophius americanus*) (southern), and scup (winter I season) (Figure 2.3).

The proposed definition for what constitutes an underutilized species has limitations. First, this definition can only be applied to managed and frequently monitored species (e.g. stocks with records of allowable catch limits, cumulative catch, determined stock statuses). Some stocks could not be fully evaluated due to inconsistent data or undetermined stock statuses (target levels, overfished, overfishing). Undetermined stock statuses excluded Northern shortfin squid (*Illex illecebrosus*), offshore hake, American plaice (*Hippoglossoides platessoides*), winter flounder, witch flounder

(*Glyptocephalus cynoglossus*), and longfin squid (*Doryteuthis pealieii*) from a full evaluation. Additionally, this definition relies on accurate and accessible information. Sourcing, identifying, and compiling up-to date information was difficult since stock-specific information was divided by different fiscal years, deposited in different online databases and reports, distributed throughout different management websites, and was frequently adjusted with updates throughout 2019 (the time period during which this evaluation was conducted). Unclear records about landings and allowable catch limits excluded the northern red hake (*Urophycis chuss*) stock from a full evaluation, which may have otherwise been a contender.

Uncertain Responses to Climate Change

Despite the assessments and projections already discussed, more research should be conducted about these fishes responses to warming conditions so markets and the fishing industry can prepare for changes in accessible supply and management regulations.

Scup and butterfish are likely to benefit from warming climate conditions; however, they were largely left out of climate studies, thus their biological and ecological responses in a warming scenario are not fully understood. For example, butterfish have ecological importance as a forage fish serving as a valuable prey species for both small and large commercial fish such as haddock, silver hake, monkfish, bluefish (*Pomatomus saltatrix)*, weakfish (*Cynoscion regalis*), and swordfish (*Xiphias gladius)* (Bigelow and Schroeder 1953; Scott and Tibbo 1968; Horn 1970; Brodziak 1995). New predators moving into northern areas from the mid-Atlantic due to climate change could increase the predatory demand on butterfish, while a decline in predatory populations due to climate change could release butterfish from natural mortality. Additional research is needed on scup and butterfish since they are important prey species and there is high uncertainty on how species interactions will change with shifts in phenology and fishing pressure (Weiskopf et al. 2020).

More life history information about white hake populations needs to be collected and analyzed. The stock's spawning cycle and location in Georges Bank - Middle Atlantic Bight is not well understood (Chang et al. 1999; Fahay and Able 1989), and it is unclear why there is a significant negative correlation between 4-year lag fall stock biomass and longer summer duration (Henderson et al. 2017).

Additional research and monitoring about how climate change will impact the distribution, population growth rate, and early life requirements of Atlantic pollock is also needed (Hare et al. 2016; NEFSC 2017). Scientists are unsure how haddock stocks will respond to climate change; while it is considered a cold-water fish, it has experienced several strong years of recruitment despite warming conditions (Hare et al. 2016; NEFSC 2017).

In addition to investigating climate-driven shifts and responses in specific species, future efforts should attempt to capture how possible shifts in phenology will create cascading impacts within fisheries (especially those managed with seasonal quotas) and within the Northwestern Atlantic ecosystem (e.g. mismatches in timing of resource availability). These research efforts could help the regional fishing industry and marketplace be prepared for system effects (Staudinger et al. 2019).

Reaching Diversified Landings and Markets

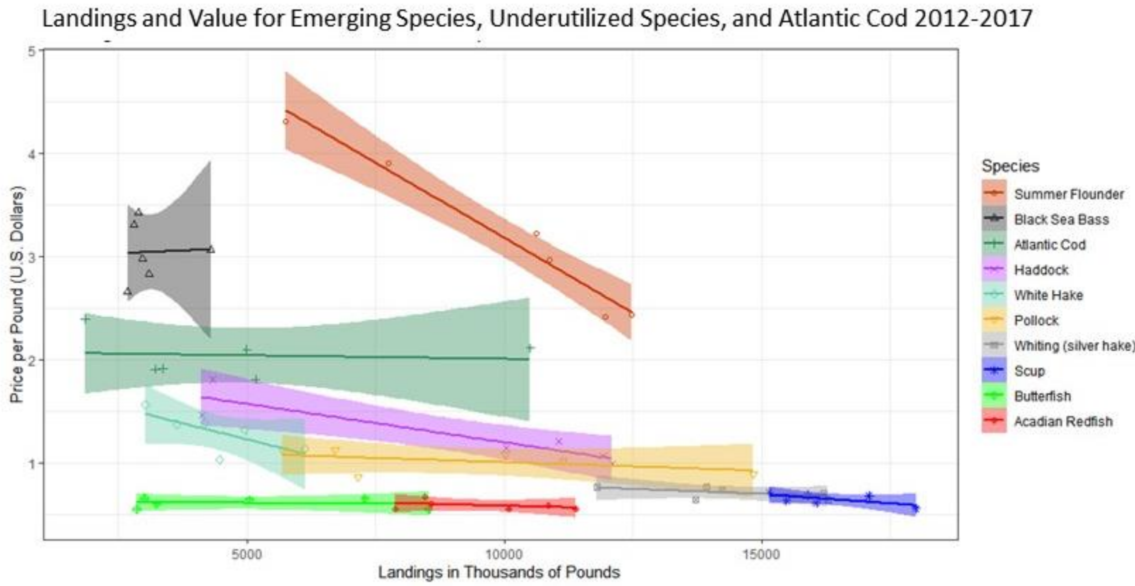


Figure 2.7: Price per pound and landings of underutilized species. Results of simple linear regressions illustrating price responses to landings for Atlantic cod, black sea bass, summer flounder, and each underutilized species. Smoothed confidence intervals of 0.95. Price per pound are ex-vessel prices that do not account for cost to lease quota. Data obtained from U.S. Fisheries of the United States (2013-2017) (NMFS 2014; NMFS 2016; NMFS 2018).

Diversifying landings is a noted climate adaptation strategy that helps fishing communities create resilience as multiple key revenue species potentially become less accessible to fishers, while other opportunities or emerging species become readily available (Young et al 2019; Food Export Northeast 2019; Gershenson 2020). For example, white hake and silver hake are top revenue earners for several ports in New England and both species have shifted northwards (Nye et al. 2009). Additional northward shifts in the white hake population may negatively affect revenue at Newington, NH and Portland, ME., while shifts in silver hake populations may negatively affect revenue at Newington, NH., New London, CT., and Point Judith, RI. (Kleisner et al. 2017). New London, CT and Point Judith, RI may be well positioned to adapt to changes in silver hake and white hake populations by pivoting toward emerging and high value species shifting in from southern waters such as black sea bass

(*Centropristis striata)* and summer flounder (*Paralichthys dentatus)*. Both summer flounder and black sea bass are significantly more valuable than white hake and silver hake (Figure 2.7). However, given their geographic position, Newington, NH and Portland, ME., will likely not be able to take advantage of emerging species to the same degree as southern New England ports. Therefore, northern New England ports may be interested in building diversity by landing more northern underutilized species while southern New England ports may build diversity using emerging species.

Regulation changes that reflect the responses by different fishes to warming temperatures are essential to help fishers reduce bycatch and diversify their landings (Pinsky and Fogarty 2012; Young et al 2019). Massachusetts has demonstrated progressive climate-related regulation changes with the Mid-Atlantic Council when they adjusted the 2020 regulations for black sea bass and summer flounder. The state increased black sea bass quota by 59% from the previous year, increased trip limits, and increased incidental catch limits to "enhance the retention of marketable fish and reduce regulatory discarding" during the squid and large mesh mixed trawl fishery. Massachusetts increased trip limits and eliminated some closed fishing days for summer flounder so fishers can better utilize the quota than previous years (Division of Marine Fisheries 2020).

The marketplace has a role in helping fishers diversify too. Currently, the top five species consumed in the United States are primarily farmed and imported (Shamshak et al. 2019). Consumers can simultaneously reduce the carbon footprint of their eating behavior and create resilience for the seafood industry in a changing climate by substituting animal proteins with high carbon footprints (e.g. red meat and imported seafood) with a variety of locally-caught wild seafood (Parker et al. 2018; McClenachan et al. 2014). Market diversity can also be viewed through the lens of seafood product preparation where a variety of preserved methods (e.g. frozen, tinned, smoked, etc.) could help fishers and marketplaces during challenging market conditions; for example, unbalanced supply and demand during COVID-19 pandemic, and during increasingly variable and extreme climate years (Danderant 2020; Overton 2020; Wells 2020).

Evaluating Short and Long-term Market Potential in a Changing Climate

Developing new markets for lesser known fish species in a changing climate will require: 1) an abundant and accessible population, 2) the ability for the population to withstand additional fishing pressure under projected future conditions, and 3) heightened interest from consumers, markets, and restaurants.

Short Term Market Potential

Currently, all underutilized species have short-term market potential because they have healthy populations, can withstand additional fishing pressure, are available to fishers despite warming temperatures, and have received positive reactions from consumers in food markets (Masury and Schumann 2018).

However, there appears to be a narrower window of opportunity to develop a market for Acadian redfish compared to the other underutilized species. Acadian redfish are slow-growing, mature later, have a lower fecundity, are expected to make significant poleward movements, and lose a significant portion of their suitable thermal habitat by the end of the century. Therefore, developing a short-term market for Acadian redfish would have to be done carefully with input from the fishing industry and fisheries scientists due to their complex life cycle, sensitivity to overfishing, and rapidly shifting center of biomass (Nye et al. 2009; Kleisner et al. 2017; Morley et al. 2018).

If a short-term market is developed for Acadian redfish, a market for Atlantic pollock could be developed in parallel since they are considered bycatch in the Acadian redfish fishery, are almost twice as valuable (Figure 2.7), and exhibit similar responses to climate change. Like Acadian redfish, they are losing suitable habitat and generally reproduce at an older age; however, Atlantic pollock can reproduce multiple times during a single season, and therefore may be more capable at replenishing its population. Developing new markets for Atlantic pollock and Acadian redfish together would provide additional financial opportunities for fishers while helping the industry reach their catch diversity and reduced bycatch goals. Industry leaders should align efforts and develop cohesive messages now if they are interested in building new markets for Acadian redfish and Atlantic pollock.

While silver hake and white hake do not appear to be as sensitive to increasing temperatures as Acadian redfish, building new markets for these species should be decided upon soon since these species are shifting northward in response to warming conditions. Consumers may be more interested in these species because they fit the white fleshed and filleted profile that is familiar to consumers (Masury and Schumann 2018); however, they are likely less expensive than other whitefish such as Atlantic cod and haddock (Figure 2.7). To avoid market confusion, industry has distinguished a difference between silver hake and white hake to consumers by giving silver hake the market name “whiting” and white hake is sold simply as “hake”.

Unlike other underutilized species, haddock does not need to overcome the challenge of consumer familiarity (Masury and Schumann 2018). However, much of the haddock consumers currently have access to is imported, and haddock is decreasing in value. In 2018, the U.S. landed 6,557 metric tons of haddock and imported 20,224 metric tons of haddock from other countries such as Norway and Iceland (NMFS 2020). Haddock landings have significantly decreased in value over the past 5 years from 2012 when landings totaled 4,342,000 pounds at $1.80/lb to 2017 with 12,101,000 pounds at $0.98/lb (Figure 2.7). It is unclear whether low haddock prices reflect increased landings, pricing pressure from imports, or quality. Since less than 50% of the ACL for both Georges Bank and Georges Bank East haddock has been utilized in 3 out of the last 5 years, fishing communities may want to identify ways to stabilize the haddock price before utilizing more of the ACL.

While there is great potential in substituting domestic haddock for imported haddock, current fishing regulations make it challenging to utilize more of the haddock ACL- or ACL of any other groundfish within the Northeast Fisheries Management Plan - because they are frequently caught simultaneously with Atlantic cod. Atlantic cod has a reputation for having a quota price greater than ex-vessel price, meaning fishers likely lose money when they catch Atlantic cod (LaCasse 2018). However, fishers generally have to purchase some Atlantic cod quota as protection because cod intermingles with other groundfish species, including haddock, Atlantic pollock, and hake. Fishers are required to stop fishing altogether if they catch more cod than their quota allows. This relationship has earned Atlantic cod the label of “choke species” (LaCasse 2018) and it is likely a key reason why species within the Northeast FMP are underutilized. Fishers may be interested in targeting more underutilized species within the Northeast FMP in the near future if they receive better prices, if gear technology advanced to better avoid or exclude cod (DeCelles et al. 2017), or if new policy frameworks create flexible and less risky arrangements when Atlantic cod are caught.

Long-Term Market Potential

Industry leaders have much more time to evaluate if they want to develop new markets for butterfish and scup. These species are expected to be both abundant and accessible in future climate conditions. One explanation for the low historic landings could be the low ex-vessel price for these fishes – between $0.55 - $0.71/lb (Figure 2.7). Low ex-vessel prices likely reflect low current demand. Butterfish and scup may be in low demand because consumers are unfamiliar with them at marketplaces and they are primarily sold whole (Masury and Schumann 2018),

Issues that butterfish will face in the marketplace are their small size, bony structure, and being sold whole. Consumers in New England are more familiar with seeing and cooking pieces of larger deboned fillets rather than small whole bone-in fish. While these characteristics are widely accepted in ethnic markets (Masury and Schumann 2018), recipes, instructional cooking videos, and social influence from restaurants may make whole butterfish more appealing to a wider consumer audience. Market confusion and mistrust already exists for butterfish – there are at least nine other species that have a Food and Drug Administration "Acceptable Market Name" of 'butterfish' (FDA 2020) and butterfish is also a widely used name for escolar *(Lepidocybium flavobrunneum),* a fish that can make consumers sick (Begos 2018). Encouraging consumers to become aware of appearance of whole butterfish and their seasonality could reduce market confusion and mistrust.

Scup are bony and primarily sold whole too, but there are efforts to create a fillet market. Consistent fillet quality is a key marketplace issue for scup. The Commercial Fisheries Research Foundation (CFRC) found: 1) the quality of scup fillets are compromised in late spring and early summer after scup spawn, and 2) the taste and texture of scup fillets is undesirable after they have been frozen and thawed (CFRC 2019). These findings suggest that the quality of fresh scup fillets from the Winter II season are suitable for consumption, but the seafood industry should work with food scientists to overcome the undesirable effects of freezing scup fillets, or explore alternative preparations (canning, smoking, etc.).

Research Needs for Climate-Smart Marketing and Consumption

Additional infrastructure, economic, management, and social information is needed to have a more holistic view of the short-term and long-term potential of these seven underutilized species. First, it is important that fishing industry professionals can realistically anticipate future revenue potential for each species if demand and/or landings increase. Stabilizing and/or increasing ex-vessel prices for these underutilized species would greatly benefit fishers. It may also be worthwhile to assess if policy frameworks could be adjusted for fishers who are hesitant to target more underutilized species because of the risk of catching Atlantic cod and increasing their costs (LaCasse 2018). More profitable ex-vessel prices for other species and reduced costs/flexible arrangements to lease quota could encourage fishers to diversify their catch and landings. Second, it is important to identify the region's current capacity to catch, process, market, and distribute an increased supply of any underutilized species. History suggests that creating new markets for low value underutilized species can promote increased processing capacity, build stronger ex-vessel prices, shift consumption habits, and encourage fishers to diversify their landings. Therefore, data gaps about current market availability, market interests, and consumer responses to underutilized species should be addressed so climate-smart consumption and marketing can be implemented effectively and responsibly in the future.

2.6 Conclusion

This study identified the finfish species in New England that could be considered for new market opportunities as part of a climate-smart strategy. The proposed definition and approach for identifying underutilized species allows regional managers to regularly assess their fish stocks on an annual basis with metrics they already use or are familiar with. The seven underutilized fish species span diverse distributions, phenologies, and responses to climate change. All underutilized species have short-term market potential but pose their own unique challenges. Future research efforts should attempt to capture how possible shifts in range and phenology will create cascading impacts within the Northwestern Atlantic ecosystem and it's regional fisheries, and ultimately, how the fishing industry and marketplaces can create profitable opportunities while adapting to system-wide effects.

CHAPTER 3

THERE'S MORE FISH THAN I SEE: EVALUATING SUSTAINABILITY MESSAGES AND CONSUMER ACCESS TO LOCAL SEAFOOD AT RESTAURANTS IN BOSTON, MASSACHUSETTS

3.1 Abstract

Capturing the current landscape of seafood offered at restaurants could help document future changes and shifting norms as seafood is incorporated into the "Eat Local" movement. This study reviewed over 140 restaurant menus from Boston, Massachusetts to: 1) capture which types of seafood are being served in Boston restaurants on a seasonal basis, 2) describe the depth of seafood transparency customers receive about popular seafood items, and 3) estimate consumer access to underutilized species. Popular seafood suggestion tools were also evaluated to identify the degree they provide adequate and consistent information about New England's underutilized species. Results suggest that well-known seafood suggestion tools did not provide adequate or consistent recommendations about each underutilized species and, except for haddock, restaurants rarely offered underutilized species as part of their summer and winter menu options. Together, these results provide a snapshot of Boston's seafood landscape and suggest that restaurants would benefit from new tools that encourage increasing participation in the "Eat Local Seafood" movement.

3.2 Introduction

The sustainable seafood movement in the United States began in the 1990s and has since included campaigns, boycotts, and consumer tools (e.g. suggestions guides and ecolabels). The overarching purpose of the movement is to build awareness and help consumers and businesses make informed seafood decisions that align with their conservation, humanitarian, and health values (Roheim and Sutinen 2006). For example, initiatives formed in response to overexploited fish stocks, health benefits, unethical labor practices, and fishing practices that harm the environment and other species (Roheim and Sutinen 2006; EDF 2008; Leschin-Hoar 2018). The sustainable seafood movement also calls for greater seafood transparency to combat mislabeling species name, country of origin, and harvest method (Jacquet and Pauly 2008). Campaigns with clear calls to action – such as the 1990's "Give Swordfish a Break" initiative – have been successful (SeaWeb 2002). Two recent sustainable seafood initiatives that are gaining traction, promote seafood transparency, and provide clear calls to action are the "Eat American Seafood" and "Eat Local Seafood" campaigns as part of the broader "eat local" movement (Brinson et al. 2011; Olson et al. 2014; McClenachan et al. 2014; Seafood Nutrition Partnership 2020).

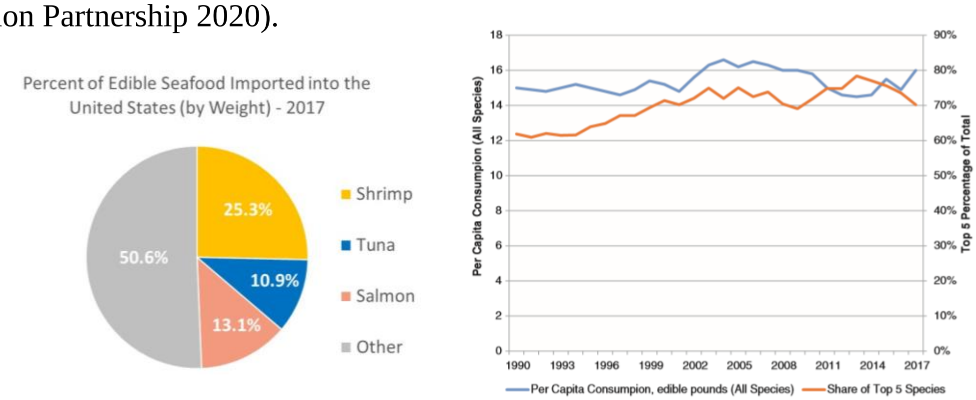


Figure 3.1A (left) and Figure 3.1B (right): A view of mported seafood in the U.S. In 2017, 5.9 billion pounds of seafood was imported into the U.S. valued at $21.5 billion. Almost half of all imports (by weight) was comprised of three seafood items: shrimp (1.5 billion pounds), fresh and frozen salmon (777.1 million pounds), and fresh, frozen, and canned tuna (643.7 million pounds) (left). Data adopted from NMFS (2018). The U.S. per capita consumption of seafood (blue) and share of the top five species consumed (orange), 1990-2017 (right). Figures adopted from Shamshak et al. (2019).

Eating more domestic and local seafood is desirable for the nation's health, economies, and overall environment. Over the past few decades, Americans have rarely adjusted the amount of seafood in their diet beyond 15-16 pounds/year (Shamshak et al. 2019). Their seafood consumption behavior has also shifted from eating primarily a mix of domestic wild-caught and imported seafood, to eating seafood that is mostly imported and farmed (Figure 3.1A and Figure 3.1B) (Shamshak et al. 2019). Shrimp, tuna, and salmon are consistently at the top of the list for most consumed seafood items and largest volume of seafood imported into America (Figure 3.1A) (Shamshak et al. 2019). Imports now make up to 91% of total seafood consumption in the United States, and it is estimated that over half of the imported seafood is farmed and arrives from Asia (NMFS 2018). Imported seafood is partially responsible for several upsets in the seafood industry including poor seafood transparency practices (Jacquet and Pauly 2008), price competition that devalues domestic seafood (Keithly et al. 2006), and high carbon footprints for certain seafood items (Parker et al. 2018; Seafood Carbon Emissions Tool 2020). Eating more domestic seafood is a powerful strategy at the individual level that could combat climate change if it encourages Americans to shift away from eating animal proteins with high carbon footprints (e.g. industrially-raised beef, imported farmed seafood) to certain domestic wild-caught fish or shellfish with low carbon footprints (Seafood Carbon Emissions Tool 2020; Parker et al. 2018). According to recent surveys, between 29% - 47% of consumers are trying to reduce, or have reduced, their red meat consumption (Darr 2017; Kaleidoscope Research Consulting 2016). Shifting the norms to eating more domestic seafood, and a diversity of seafood, could be a bottom-up approach that would help fishing communities create resilience in a changing climate by increasing value for fishers (Keithly et al. 2006; McClenachan et al. 2014; Stoll et al. 2015) and encouraging fishers to diversify their landings (Young et al. 2019).

Approximately 2/3 of all consumer spending on seafood in America – almost $70 billion - occurred outside of the home in 2017 (NMFS 2018). Therefore, restaurants appear to be the prime place where Americans could shift from eating imported seafood to domestic and local seafood.

Incorporating more locally sourced seafood onto menus is not a new concept for restaurants. Since 2016, the National Restaurant Association has conducted an annual survey with chefs across the United States about food trends in restaurants. Out of 130 potential trends, "sustainable seafood" or "local sourced seafood" have been listed within the top 5 trends every year from 2016-2019 (National Restaurant Association 2016, 2017, 2018a, b).

It appears that sourcing local seafood may shift from a "trend" to becoming a new "norm" in restaurants. Chefs state that sourcing local food is one popular way restaurants are integrating sustainability practices into their businesses (National Restaurant Association 2018b). Recent guides and videos led by prominent chefs such as Get Hooked on Sustainable Seafood with Barton Seaver (National Restaurant Association and US Foods 2019) and chef-led local seafood events (Chefs Collaborative 2018) emerged to help other chefs and restaurant owners select and source local seafood. While this suggests that the "eat local seafood" campaigns may influence restaurants, the current norm at restaurants - and marketplaces - appears to be a consistent offering of shrimp, tuna, and salmon, even in vibrant fishing communities like New England (Masury and Schumann 2019). Capturing the current landscape of seafood at restaurants could help document future changes and shifting norms. Temporal changes in seafood use has been captured through restaurant menu assessments (Miller et al. 2012).

Restaurants may want resources that help their staff and guests achieve sustainability goals and that reflect a region's local seafood options. Popular tools such as ecolabels (e.g. Marine Stewardship Council), sustainability guides (e.g., Seafood Watch from Monterey Bay Aquarium), and chef-centered commitment programs like Smart Catch (James Beard Foundation 2020) have been key to developing restaurants' involvement in sustainable seafood and seafood transparency. However, these popular resources often rely on each other (e.g. James Beard Foundation's Smart Seal relies on rankings from Seafood Watch) and may disqualify a region's emerging fishery or lesser known fishery because it lacks a long-term or updated dataset (Seafood Watch 2020). Some tools have also confused consumers (Roheim 2009; Seaman 2009), fueled disagreements among industry professionals (Jacquet and Pauly 2007; Roheim 2009),and may have driven some consumers to make fewer seafood purchases altogether (Hallstein and Villas-Boas 2013). Therefore, new resources that resolve previous shortcomings and fill remaining gaps may help restaurant staff and guests participate in the "Eat Local Seafood" and "Eat American Seafood" campaign long-term.

Restaurants in Boston, Massachusetts appear especially well positioned to provide local seafood and seafood transparency to consumers. Boston boasts the historic Boston Fish Pier which has been selling seafood since 1914 (Clauss 2017), and is geographically positioned between major New England fishing ports such as New Bedford, MA, Gloucester, MA, Point Judith, RI, and Portland, ME. The Boston Fish Pier provides food distributors, and therefore restaurants, access to all of New England's local seafood, including all seven of the underutilized species identified in Chapter 2 - Acadian redfish, Atlantic pollock, butterfish, scup, silver hake, white hake, and haddock. Boston restaurants also have access to industry leaders, networks, and advocates in New England who are spearheading New England's Eat Local Seafood campaign. (Red's Best 2015; Seafood Solutions 2018; Masury and Schumann 2019; McMahon 2020; Our Wicked Fish 2020).

This study reviewed over 140 restaurant menus from Boston, Massachusetts over two seasons to: 1) capture which types of seafood are being served in Boston restaurants during the Eat Local Seafood movement, 2) describe the depth of seafood transparency customers receive about popular seafood items, and 3) estimate consumer access to underutilized species. I also evaluated if popular seafood suggestion tools provide adequate information to Boston restaurants about New England's underutilized species. Together, these results provide a snapshot of Boston's seafood landscape and suggest if restaurants would benefit from new tools during the Eat Local Seafood and Eat American Seafood movements.

3.3 Methods

3.3.1 Current Access to Underutilized Species in Restaurants

Data Collection

Restaurant Database

A database of restaurants within Boston, Massachusetts, was created using information from Yelp.com - a popular business directory and crowd-sourced review platform. The city of Boston was the target region because restaurants have full access to locally caught seafood, including all fish species classified as underutilized in Chapter 2, from seafood processors and distributors at the Boston Fish Pier.

Restaurant menus were assessed using the following criteria: the restaurant 1) was located within Boston's principal neighborhoods; 2) identified itself on Yelp.com as a seafood restaurant, or did not exclusively identify as a specialized or ethnic restaurant; and 4) identified its value on Yelp.com as "$", "$$", or "$$$" out of a "$-$$$$" scale. Restaurant menus were excluded from the review if the restaurant: 1) did not have an online website that displayed the menu, or 2) did not include prices on the online menu. Restaurants that identified exclusively as either a specialized restaurant (e.g. sushi, juice bar, vegan) or ethnic restaurant (e.g. Japanese) were excluded to reduce the size of the database and reduce the possibility of including extremely biased levels of seafood contributions to the database (e.g. sushi restaurant versus a juice bar). These inclusion and exclusion criterion weres also designed to capture the restaurant menus that would interest a broad scope of consumers and food preferences. The menu assessment protocol was created, tested, and revised in summer 2018. Each restaurant's menu was assessed for two seasonal menu offerings: winter 2019 (January-February) and summer 2019 (August – September). Recorded information from each menu included:

1. The presence or absence of over 60 different types of seafood (1=present, 0=absent).
2. Proportion of appetizers on each menu containing seafood.
3. Proportion of entrees on each menu containing seafood.
4. Price of each dish containing seafood (in US dollars or "M" for "market price")

When a menu sold individual shellfish items (e.g. a single oyster), the price of a dozen shellfish items was entered into the database to match the serving size, and therefore price, that other restaurants provided. Some seafood items were listed on menus as general terms that described multiple species (just “tuna” as opposed to “yellowfin tuna”) or may/may not have included harvest method (wild-caught vs. farmed). Species information and harvest method are two levels of seafood transparency that consumers need if they want to use certain seafood suggestion guides to make an informed decision. Therefore, two levels of seafood transparency were recorded for certain commonly offered seafood items:

1. Harvest method (f=farmed, w=wild-caught, u=unidentified) was specified if salmon and shrimp were present on a menu.
2. Specific species were recorded if salmon, tuna, or crab, were present on a menu, (e.g., b=bluefin tuna, a=albacore tuna, k=king crab, u=unidentified, etc.).

Data were recorded in the restaurant database. Screenshots of each online menu were captured and filed during the winter 2019 and summer 2019 assessment.

The restaurant database was originally comprised of 161 restaurants. Restaurants were excluded from analyses if the restaurant was not eligible for assessment during both winter and summer season. A total of 4 restaurants were ineligible for the winter 2019 assessment and 8 additional restaurants were ineligible for the summer 2019 assessment. Restaurants were ineligible for assessment if they were either no longer in business or they removed prices from their online menu between the two seasonal evaluation periods. Of the remaining 149 restaurants, there were 4 restaurants that had multiple locations (between 2-4 locations). Each location was treated as a separate menu since the restaurants with multiple locations tended to offer a different menu at each location.

Data Analysis

Percent Seafood, Total Seafood Items, Richness, Abundance, Frequency of Occurrence, and Diversity

Percent seafood was calculated for each menu as the number of dishes containing seafood (appetizer + entrée) divided by the total number of dishes (appetizer + entrée) and then multiplied by 100. Total seafood items were calculated as the number of different seafood items found on each restaurant's menu. A Wilcoxon rank-sum test was conducted to compare percent seafood by restaurant type (seafood vs. non-seafood), and total seafood items per restaurant by restaurant type (seafood vs. non-seafood). A Kruskal Wallis test was conducted to compare seafood richness by neighborhood, and total seafood items per restaurant by neighborhood. Nonparametric analyses were found to be most appropriate for these comparisons due to violations in assumptions of normality in the datasets.

When a seafood item was identified to the species level on a menu (e.g. "tuna" was listed as "yellowfin tuna") or by harvest method (e.g. "salmon" was listed as "wild king salmon"), items were further described by "seafood type". Items that were not identified to the species or harvest level, were considered "unidentified" (e.g. "unidentified tuna" or "unidentified salmon"). While "whitefish" descriptions were considered "unidentified fish" during the winter assessment, this description received its own category during the summer assessment after a seafood sustainability guide for chefs suggested that chefs use the term to allow flexibility in which fish they could offer customers (National Restaurant Association and US Foods 2019).

Seafood richness (S) was calculated using the number of different seafood types found during each season. Unidentified items, "Lump crab", "Sea bass", and "Fish of the Day" were included in the seafood richness calculation because they accurately describe types of seafood that this study aimed to document. Whitefish was not considered a seafood item when calculating seafood richness because it was only accounted for on summer menus.

Total abundance (A) was calculated as the total number of times a seafood type was found in a dish (appetizer + entrée). Frequency of occurrence (%FO) among all seafood dishes was calculated by dividing the total abundance (A) by the total count of seafood dishes found within the season then multiplying by 100. Total abundance and %FO were calculated seasonally for each seafood type.

Seafood diversity within each season was calculated using the Shannon-Wiener Diversity Index (H′):

$$H' = \sum p_i \, ln\,(p_i)$$

where p_i is the count of the seafood type found on menus during the ith season. Shannon's equitability (E_H) described how evenly seafood items were distributed across menus. Equitability assumes a value between 0 and 1, with 1 indicating complete evenness (Shannon & Weaver, 1949).

$$H_{max} = lnS$$

$$E_H = H' / H_{max}$$

Seafood Transparency

The two levels of seafood transparency – harvest method and species - were calculated by counting the total number of restaurants that provided a level of seafood transparency to customers, either by listing harvest method and/or species. Harvest level (e.g., wild, farmed) was assessed when a restaurant offered salmon or shrimp. Species level was assessed when a restaurant offered salmon, tuna, crab, bass, or trout.

Access to Underutilized Species

Consumer access to each underutilized species was calculated by counting the number of restaurants that offered at least one underutilized species and comparing the %FO of each underutilized species across restaurants.

Price of Seafood Types

Prices of appetizers and entrees that contained each seafood type were combined from both seasonal assessments. Descriptive statistics (median, mean, and standard deviation) assessed prices of appetizers and entrees containing unidentified fish, all 7 underutilized species, Atlantic cod and unidentified cod, and the top 10 most frequently occurring seafood types. This selection of seafood types allowed comparisons between underutilized species, popular yet overfished species in the United States (e.g. Atlantic cod), and other popular seafood types. Dishes marked "market price" were omitted from the calculations because a price was not available. Appetizers above $55 and entrees above $75 were also omitted from the calculations because these prices stem from different sizes of "seafood towers" which include many seafood types rather than dishes containing one or two seafood types.

3.3.2 Current Consumption Suggestions About Underutilized Species to Consumers

Seafood recommendations from popular seafood suggestion guides were collected and recorded for the 7 underutilized species (identified in Chapter 2) in August 2018. Online seafood suggestion guides were collected from the following organizations: 1) Seafood Watch (Northeast U.S. region guide) by Monterey Bay Aquarium, 2) Fish Watch by NOAA, 3) Marine Stewardship Council (MSC), 4) Seafood Selector from the Environmental Defense Fund (EDF), and 5) The Safina Center. Then, ratings from Fish

Watch, MSC, and the Safina Center were translated into a traffic light ranking scheme (e.g. green, yellow, or red to represent "Best choice", "Good alternative", and "Avoid", respectively) to match the ranking system used by Seafood Watch and EDF (Table 3.1). The traffic light ranking scheme was used as the standard approach because of the ease of use and popularity (Seafood Watch app and pocket guide has been distributed over 20 million times from 1999 to 2010) (Kemmerly and Macfarlane 2008; Roheim 2009).

The MSC ratings for "saithe" were used for Atlantic pollock since saithe is an alternative market name for the species. If an organization did not provide a ranking for an underutilized species, the recommendation was left blank. Message consistency was evaluated for each underutilized species by comparing rankings from each organization.

	Criteria Evaluated	Best Choice	Good Alternative	Avoid
Seafood Watch	Scores on 4 Criteria: Impacts on the species (abundance & fishing mortality), Impacts on Other Captured Species, Management Effectiveness, Impact on the Habitat and Ecosystem	Final Score >3.2, and either Criterion 1 or Criterion 3 (or both) is Green, and no Red Criteria, and no Critical scores	Final score >2.2, and no more than one Red Criterion, and no Critical scores, and does not meet the criteria for Best Choice (above)	Final Score ≤2.2, or two or more Red Criteria, or one or more Critical scores.
Fish Watch	Provides information on the population level, fishing rate, bycatch, and habitat impacts. Scored according to population level and fishing rate.	above target population levels, fishing rate at recommended levels	population below target levels, fishing rate at recommended levels	below target population levels or unknown, fishing rate reduced to end overfishing
MSC	Based on MSC Certified "Fish to Eat"	MSC certified	--	
EDF	Provides an Eco-rating, mercury rating, recommended servings per month by sex and age, and "Eco details".	Fish from healthy, well-managed populations, and the fishing or farming methods used to catch or raise the fish cause little harm to the environment.	have improvments to make in how they are managed, the health of their habitat, or how they are caught or farmed.	are overfished or caught or farmed in ways that do considerable harm to the environment.
Safina Center	Acknowledges using same criteria and methodology as Seafood Watch. Also considers contamination	Species is relatively abundant, and fishing methods cause little damage to habitat and other wildlife.	Some problems exist with this species' status or catch methods, or information is insufficient for evaluating.	Species has a combination of problems such as overfishing, high bycatch, and poor management.

Table 3.1: Translation of rating criteria to traffic light ranking scheme. Rating criteria from the Fish Watch, Marine Stewardship Council, and the Safina Center were translated into a traffic light ranking scheme. The Environmental Defense Fund (EDF) and Seafood Watch from the Monterey Bay Aquarium already use a traffic light scheme approach to communicate seafood sustainability messages to consumers. Species in green are considered 'Best Choice', yellow are 'Good Alternatives', and red species are on the 'Avoid' list

3.4 Results

3.4.1 Current Access to Specific Seafood Species in Restaurants

Overview

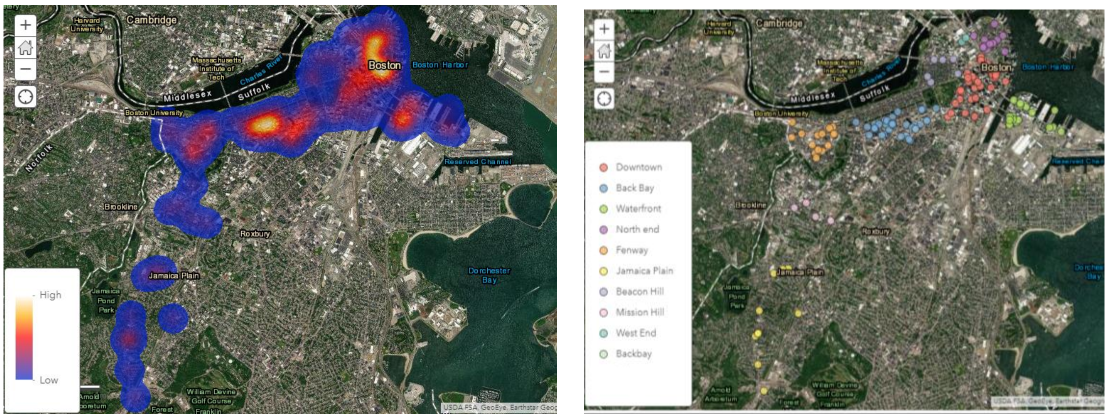


Figure 3.2A (left) and Figure 3.2B (right): Location of Boston restaurants. A map showing the density of restaurants included in the assessment where warmer colors indicate areas where there were of high density of restaurants from this assessment (left). The location of restaurants included in this assessment were colored by neighborhood (right).

The restaurant database was originally comprised of 161 restaurants. A total of 149 restaurants met all criteria for evaluation and were assessed for both the summer and winter seasons (Figure 3.2A). A summary of restaurants by location is found in Table 3.2. Over 50% of the restaurants, including 22 of the 40 restaurants that identified as a “seafood” restaurant, were located in Downtown and Back Bay (Table 3.2). Over 60% of the restaurants were moderately priced (listed as $$) according to Yelp.com.

A total of 6,694 dishes (1,943 appetizers and 4,751 entrees) were assessed during the winter assessment and 6,778 dishes (1,588 appetizers and 5,190 entrees) during the summer assessment. The median number of appetizers offered at any one restaurant was 12 in the winter and 10 in the summer. The median number of different entrée options offered at any one restaurant was 24 in the winter and 28 in the summer. Three restaurants offered over 100 different entrée options. Seafood was a component of 33%

of all dishes offered across all restaurants in both seasons. Seafood was found more often in an appetizer than in an entrée (38% and 40% of all appetizers contained seafood during the winter and summer, respectively).

A total of 54 seafood items were identified across all menus during both seasons (Table 3.3). Four seafood items – shrimp, salmon, clams, and tuna – were found on almost 50% or more of the menus during both assessments. The most common underutilized species found on menus was haddock (~19% of the menus during both seasons). Besides haddock, underutilized species were only found on ≤ 3% of the menus.

Boston Neighborhood	Total #	Percent of Total (%)	# Seafood	$	$$	$$$
Downtown	41	28	10	10	27	4
Back Bay	36	24	12	3	20	13
Waterfront	18	12	7	0	13	5
North End	16	11	9	1	12	3
Fenway	15	10	2	2	11	2
Jamaica Plain	10	7	0	1	8	1
Beacon Hill	6	4	0	1	5	0
Mission Hill	3	2	0	1	3	0
West End	2	1	0	1	1	0
Longwood	1	1	0	0	1	0
Total	149	**100%**	**40**	20	101	28

Table 3.2 Demographics of 149 assessed restaurants. Demographics include the neighborhood location, the total number of restaurants within that neighborhood (range from 1-41), total number of restaurants that are self-determined seafood restaurants (n=40) and the number of restaurants within each price point on a $-$$$ scale according to Yelp.com

	Winter		Summer	
Seafood Item	Menu Count	% of Menus	Menu Count	% of Menus
Shrimp, Assorted	95	63.8	95	63.8
Clams	88	59.1	90	60.4
Salmon, Assorted	81	54.4	71	47.7
Tuna, Assorted	78	52.4	85	57.1
Haddock	29	19.5	28	18.8
Hake	3	2.0	0	0.0
Scup	3	2.0	1	0.7
Pollock	1	0.7	2	1.3
Redfish	1	0.7	1	0.7
Lobster	65	43.6	71	47.7
Mussels	59	39.6	51	34.2
Squid	52	34.9	62	41.6
Scallops	50	33.6	55	36.9
Oysters	48	32.2	48	32.2
Crab, Assorted	45	30.2	51	34.2
Unidentified Fish	38	25.5	35	23.5
Cod	37	24.8	35	23.5
Swordfish	24	16.1	24	16.1
Octopus	16	10.7	19	12.8
Anchovy	13	8.7	14	9.4
Halibut	12	8.1	18	12.1
Fish of the Day	11	7.4	7	4.7
Shellfish	11	7.4	4	2.7
Trout, Assorted	11	7.4	8	5.4
Bass, Assorted	9	6.0	18	12.1
Monkfish	6	4.0	4	2.7
Caviar	5	3.4	5	3.4
Mahi Mahi	5	3.4	4	2.7
Scrod	4	2.7	5	3.4
Snapper	4	2.7	5	3.4
Sole	4	2.7	5	3.4
Bluefish	3	2.0	4	2.7
Skate	3	2.0	2	1.3
Urchin	3	2.0	2	1.3
Arctic Char	2	1.3	3	2.0
Branzino	2	1.3	2	1.3
Catfish	2	1.3	2	1.3

Dorade	2	1.3	0	0.0
Flounder	2	1.3	1	0.7
Kampachi	2	1.3	3	2.0
Mackerel	2	1.3	1	0.7
Tilapia	2	1.3	2	1.3
Cockles	1	0.7	2	1.3
Conch	1	0.7	1	0.7
Cuttlefish	1	0.7	1	0.7
Eel	1	0.7	2	1.3
Grouper	1	0.7	1	0.7
Hamachi	1	0.7	1	0.7
Jellyfish	1	0.7	1	0.7
Langoustines	1	0.7	1	0.7
Sardines	1	0.7	1	0.7
Sea Bream	1	0.7	0	0.0
Fluke	0	0.0	2	1.3
Razor Clams	0	0.0	1	0.7

Table 3.3: The presence of each seafood item found during each seasonal assessment. Seafood items that were present on ≥50% of the menus during either season are highlighted in yellow. Underutilized species are highlighted in green. All other seafood items are listed in descending order from greatest to least occurrence during the winter assessment. Butterfish and whiting were not found on any menus during either season.

Comparing Seafood by Restaurant Type and Neighborhood

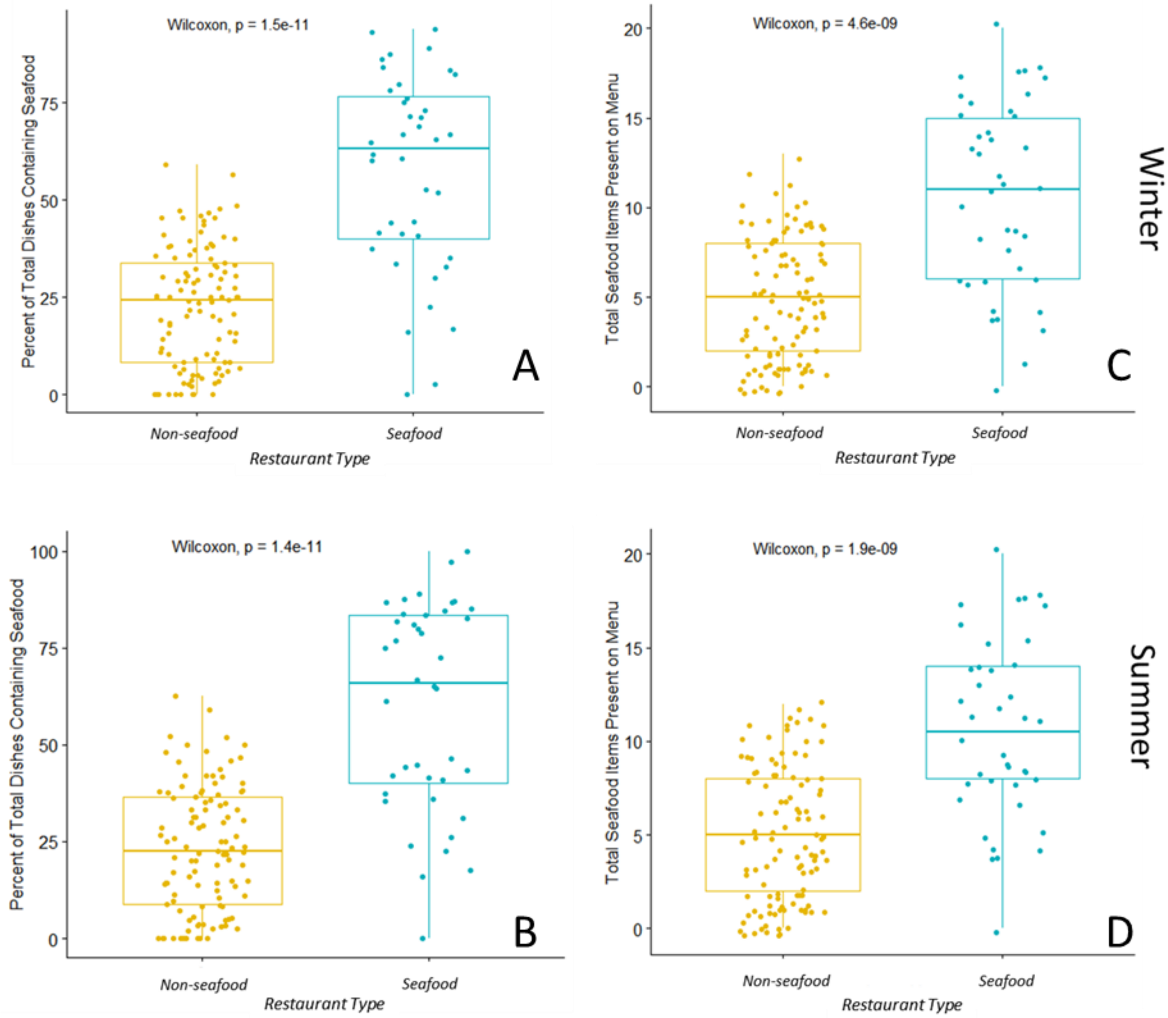


Figure 3.3: Boxplots comparing non-seafood restaurants and seafood restaurants. Boxplots compare the 1) percent of total dishes containing seafood by restaurant type (non-seafood restaurants and seafood restaurants (panel A and panel B), and 2) boxplots comparing the total number of seafood items on menus by restaurant type (panel C and panel D). Data from non-seafood restaurants are colored yellow and data from seafood restaurants are colored blue. Results from Wilcoxon Rank Sum Tests suggest that percent of total dishes containing seafood and the number of seafood items on menus differ by restaurant type ($p<0.05$) in both winter (top) and summer (bottom).

During the winter, seafood restaurants had significantly more ($W = 604.5$, p-value < 0.0001) dishes that contained seafood (median= 63.1%, mean=57% ±25.2%) than non-seafood restaurants (median= 24.2%, mean=22.6% ±15.3% dishes) (Figure 3.3). Seafood restaurants also had more seafood items ($W = 815$, p-value < 0.0001) on their menu (median=11, mean=10.8 ± 5.3) than non-seafood restaurants (median= 5, mean=4.75

±3.37) (Figure 3.3). Analyses for the summer assessment yielded similar results (p-values <0.05) (Figure 3.3).

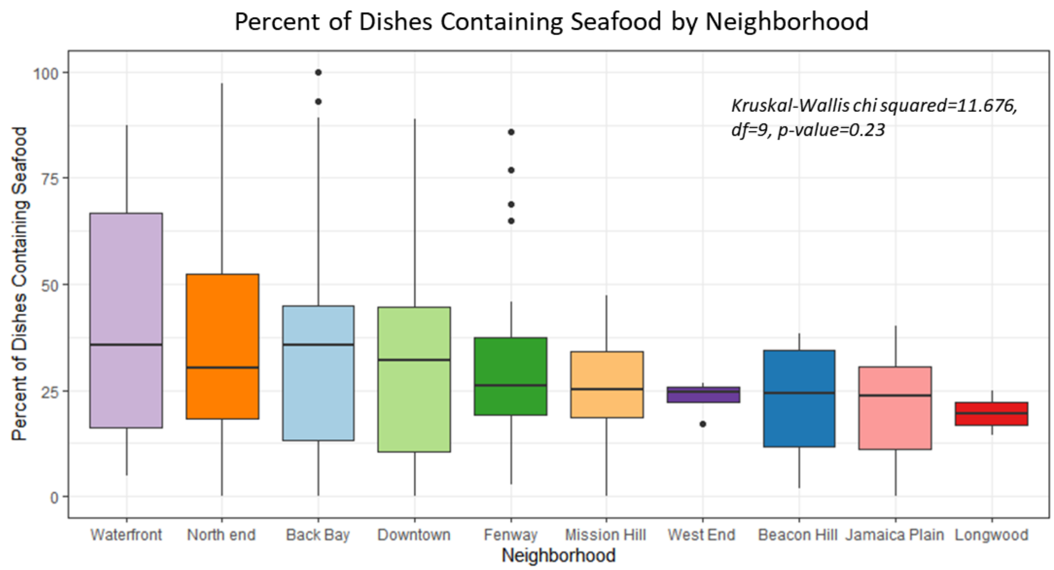


Figure 3.4: Boxplots comparing the percent of total dishes containing seafood by neighborhood.

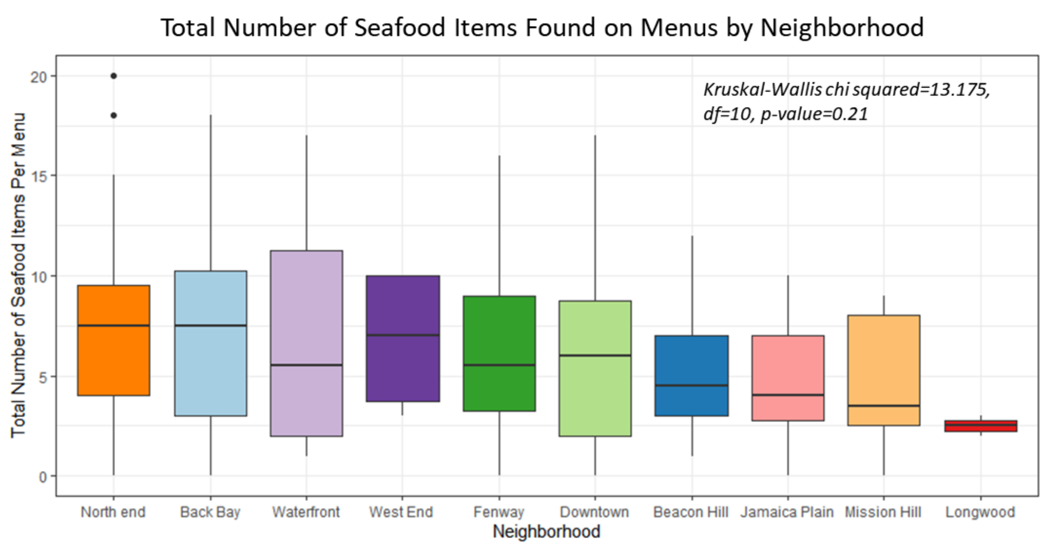


Figure 3.5: Boxplots comparing the percent total number of seafood items per menu by neighborhood.

The percentage of dishes containing seafood (Figure 3.4) and the total number of seafood items offered per menu (Figure 3.5) were similar throughout Boston neighborhoods (p-values >0.05).

Richness, Abundance, Diversity, and Evenness

A total of 76 seafood types were identified across both assessments (Table 3.4). Seafood richness (S) was slightly higher in the winter (72 items) compared to summer (69 items) (Figure 3.6A and Table 3.4). Total abundance ranged from 0 – 451 for each seafood type in a single season (Figure 3.6A). Unidentified shrimp had the greatest total abundance. In both seasons, 5 seafood types – unidentified shrimp, lobster, unidentified salmon, clams, and unidentified tuna – were the most frequently occurring seafood types across all seafood dishes (5.6% - 19% of all seafood dishes) (Table 3.4).

Seafood diversity was greater in winter (H'=3.05) compared to summer (H'=2.95). Equitability was low in both seasons ($E_{H\ winter}$ = 0.41 and $E_{H\ summer}$ = 0.38).

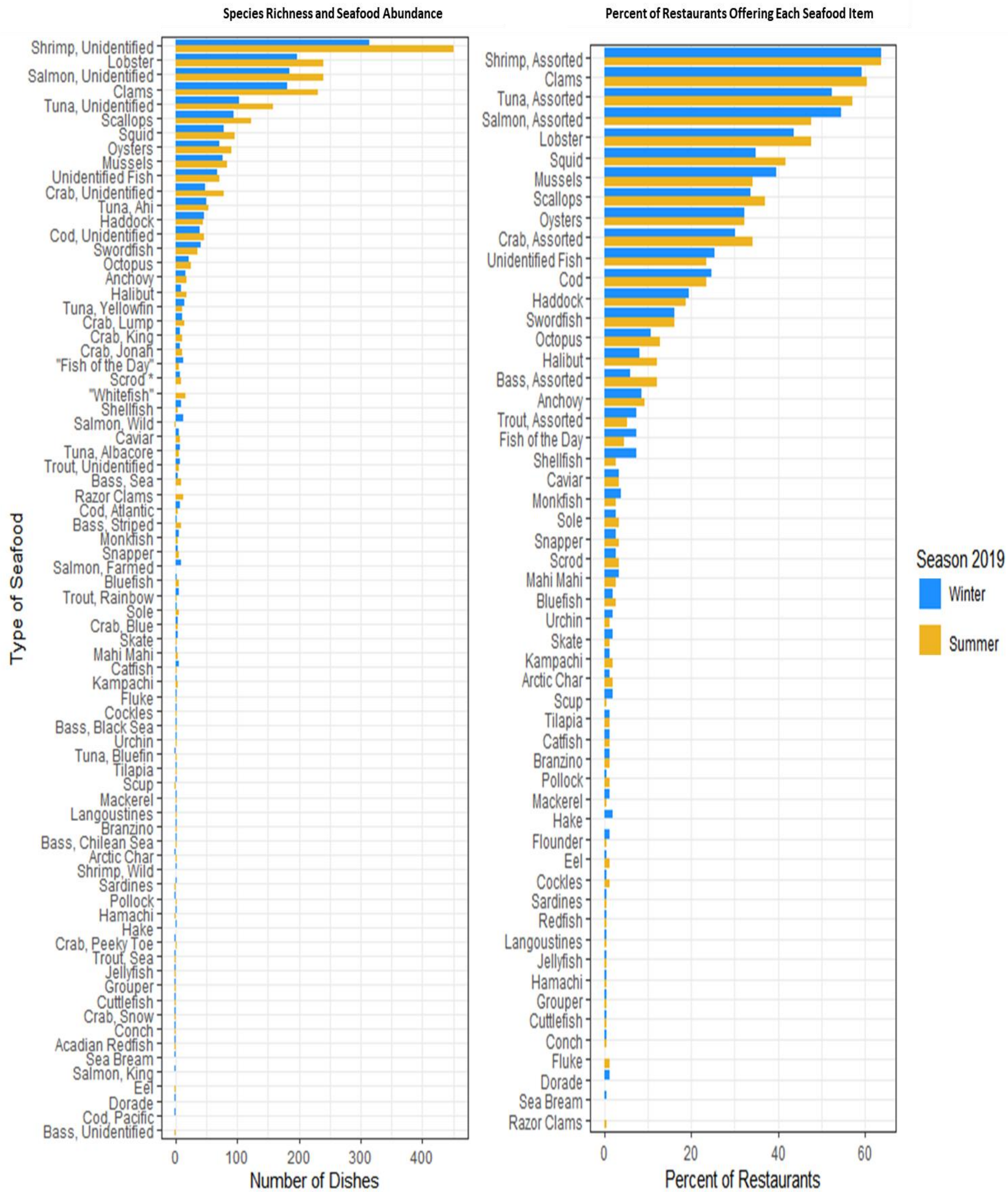


Figure 3.6A (left) and 3.6B (right): Seafood abundance and prevalence. Seafood abundance (the total number of times a seafood type appeared in an appetizer and entrée) (left) and the percent of restaurants that offered each of the seafood items during each assessment (right). Blue bars show data from the winter assessment and orange bars show data from the summer assessment.

	Winter				Summer			
Seafood Species/Types	**Appetizers**	**Entrees**	**Total**	**%FO**	**Appetizers**	**Entrees**	**Total**	**%FO**
Shrimp, Unidentified	114	200	314	17.0	115	336	451	19.5
Lobster	52	145	197	10.7	56	183	239	10.3
Salmon, Unidentified	36	148	184	10.0	14	225	239	10.3
Clams	110	71	181	9.8	118	113	231	10.0
Tuna, Unidentified	34	70	104	5.6	33	125	158	6.8
Haddock	6	41	47	2.5	5	40	45	1.9
Hake	0	3	3	0.2	0	0	0	0.0
Scup	0	3	3	0.2	0	1	1	0.0
Acadian Redfish	0	1	1	0.1	0	1	1	0.0
Pollock	0	1	1	0.1	0	2	2	0.1
Scallops	13	81	94	5.1	17	105	122	5.3
Squid	49	30	79	4.3	60	37	97	4.2
Mussels	42	34	76	4.1	42	42	84	3.6
Oysters	67	5	72	3.9	81	9	90	3.9
Unidentified Fish	28	40	68	3.7	22	49	71	3.1
Tuna, Ahi	22	28	50	2.7	11	43	54	2.3
Crab, Unidentified	25	24	49	2.7	26	52	78	3.4
Swordfish	0	41	41	2.2	0	35	35	1.5
Cod, Unidentified	1	38	39	2.1	4	42	46	2.0
Octopus	13	9	22	1.2	16	10	26	1.1
Anchovy	8	8	16	0.9	2	16	18	0.8
Tuna, Yellowfin	9	5	14	0.8	5	6	11	0.5
Salmon, Wild	4	9	13	0.7	0	1	1	0.0
"Fish of the Day"	2	10	12	0.7	0	6	6	0.3
Crab, Lump	7	4	11	0.6	9	5	14	0.6
Halibut	1	9	10	0.5	2	16	18	0.8
Shellfish	6	4	10	0.5	1	3	4	0.2
Salmon, Farmed	0	9	9	0.5	0	0	0	0.0
Cod, Atlantic	2	6	8	0.4	1	3	4	0.2
Trout, Unidentified	2	6	8	0.4	1	4	5	0.2
Crab, Jonah	4	3	7	0.4	8	3	11	0.5
Crab, King	5	2	7	0.4	5	6	11	0.5
Scrod *	0	7	7	0.4	0	10	10	0.4
Tuna, Albacore	0	7	7	0.4	4	2	6	0.3
Caviar	5	1	6	0.3	5	3	8	0.4
Monkfish	0	6	6	0.3	1	3	4	0.2
Catfish	2	3	5	0.3	1	1	2	0.1
Trout, Rainbow	1	4	5	0.3	0	3	3	0.1
Bass, Sea	1	3	4	0.2	2	7	9	0.4
Crab, Blue	4	0	4	0.2	2	2	4	0.2

Skate	1	3	4	0.2	2	1	3	0.1
Snapper	2	2	4	0.2	1	4	5	0.2
Bass, Black Sea	1	2	3	0.2	1	1	2	0.1
Bluefish	3	0	3	0.2	3	3	6	0.3
Mahi Mahi	2	1	3	0.2	1	3	4	0.2
Shrimp, Wild	2	1	3	0.2	0	0	0	0.0
Sole	0	3	3	0.2	0	5	5	0.2
Bass, Chilean Sea	0	2	2	0.1	0	2	2	0.1
Bass, Striped	1	1	2	0.1	4	6	10	0.4
Branzino	0	2	2	0.1	0	2	2	0.1
Cockles	0	2	2	0.1	0	3	3	0.1
Fluke	1	1	2	0.1	2	1	3	0.1
Hamachi	2	0	2	0.1	0	1	1	0.0
Kampachi	2	0	2	0.1	4	0	4	0.2
Langoustines	0	2	2	0.1	0	2	2	0.1
Mackerel	1	1	2	0.1	1	1	2	0.1
Sardines	1	1	2	0.1	0	1	1	0.0
Tilapia	0	2	2	0.1	2	0	2	0.1
Urchin	2	0	2	0.1	1	1	2	0.1
Arctic Char	0	1	1	0.1	0	3	3	0.1
Cod, Pacific	0	1	1	0.1	0	0	0	0.0
Conch	1	0	1	0.1	1	0	1	0.0
Crab, Snow	1	0	1	0.1	0	1	1	0.0
Crab, Peeky Toe	1	0	1	0.1	1	1	2	0.1
Cuttlefish	0	1	1	0.1	0	1	1	0.0
Dorade	0	1	1	0.1	0	0	0	0.0
Grouper	0	1	1	0.1	0	1	1	0.0
Jellyfish	0	1	1	0.1	0	1	1	0.0
Salmon, King	1	0	1	0.1	0	0	0	0.0
Sea Bream	0	1	1	0.1	0	0	0	0.0
Trout, Sea	0	1	1	0.1	0	1	1	0.0
Tuna, Bluefin	1	0	1	0.1	2	1	3	0.1
Bass, Unidentified	0	0	0	0.0	0	1	1	0.0
Eel	0	0	0	0.0	0	1	1	0.0
Razor Clams	0	0	0	0.0	12	0	12	0.5
"Whitefish"	0	0	0	0.0	2	15	17	0.7

Table 3.4: Presence and frequency of seafood species/types. A list of all 76 seafood species/types found during the seasonal assessment and their frequency of occurrence (%FO) for each seasonal assessment. These seafood species (except for "Whitefish") are used to calculate seafood richness. The top 5 most frequently found seafood types are highlighted in yellow. Underutilized species are highlighted in green. The rest of the seafood species/types are listed in descending order from highest to lowest %FO according to winter assessment values. Butterfish and whiting were not found on any menus during these assessments and are therefore not listed.

Access to Underutilized Species

Haddock was the most frequently found underutilized species across all Boston restaurant menus. Haddock was found at 29 restaurants during the winter and 28 out of the same 29 restaurants during the summer (Figure 3.6B). Between 1.9%-2.5% of all seafood dishes in Boston featured haddock (Table 3.4). Of the 28 restaurants that offered haddock during the summer, 9 identified themselves as a seafood restaurant, over half rated themselves at the mid-price range ($$ out of $-$$$), and these restaurants spanned across all Boston neighborhoods except Longwood. Haddock was more commonly found in an entrée than in an appetizer. The median price of haddock was $14 in an appetizer and $19 in an entrée.

Pollock was found at one restaurant in Back Bay and one restaurant in Jamaica Plain during the summer (Figure 3.6B). Both restaurants were mid-priced and offered pollock as an entrée at $27 and $30. The same restaurant in Back Bay was the only restaurant to offer pollock during winter. The dish was a $26 entrée.

Acadian redfish was found once per season at the same restaurant in the North End (Figure 3.6B). The restaurant was a seafood restaurant at the highest price point ($$$). During both seasons Acadian redfish was offered as a $27 entrée.

Scup was found at three restaurants during the winter and at one restaurant during the summer (Figure 3.6B). During the winter, the restaurants were in Downtown, Back Bay, and Fenway and all were mid-priced. The Back Bay and Fenway restaurants were seafood restaurants and the Downtown restaurant was not. During winter, scup was offered as an entrée for $10, $20, and $22. During the summer, the same Downtown restaurant offered scup as part of a $20 entrée.

Hake was found at three restaurants during the winter (Figure 3.6B). Two restaurants were high priced seafood restaurants in the Waterfront and one restaurant was a mid-priced non-seafood restaurant in Back Bay. At all three of the restaurants hake was offered in an entrée at $23, $26, and $27. Hake was not found during the summer assessment.

The other underutilized species – whiting and butterfish – were not found on any restaurants in either season (Figure 3.6B). In total, 8 restaurants are responsible for the 12 instances all underutilized species (except for haddock) were found in Boston.

Price

Seafood Type (Appetizer)	Count	Median	Mean	SD
Cod, Atlantic	3	4	6	5.3
Unidentified Fish	42	8.99	11.7	10.8
Cod, Unidentified	5	12	12.2	1.1
Haddock	11	14	13.5	4
Clam	189	10	13.7	9.1
Squid	108	14	14	2.7
Salmon, Unidentified	50	14	14.3	4.4
Mussel	82	14.5	14.4	2.1
Scallops	30	17	16.3	3.5
Crab, Unidentified	48	16	16.6	5.3
Lobster	80	16	16.7	7.3
Tuna, Unidentified	64	16	17.1	7.2
Shrimp, Unidentified	204	15.5	18.4	10.5
Oyster	109	35	29.6	10.8

Seafood Type (Entrée)	Count	Median ($)	Mean ($)	SD ($)
Tuna, Unidentified	180	14.0	15.6	7.4
Scup	4	20.0	18.0	5.4
Unidentified Fish	80	17.0	18.3	7.3
Oyster	9	18.0	19.8	9.7
Clam	158	18.0	19.9	10.9
Haddock	78	18.5	20.1	6.3
Cod, Unidentified	75	18.0	21.1	7.9
Salmon, Unidentified	369	22.0	21.7	5.6
Shrimp, Unidentified	522	20.0	21.9	7.0
Crab, Unidentified	72	23.0	23.3	9.0
Cod, Atlantic	6	21.5	24.5	11.6
Hake	3	26.0	25.3	2.1
Squid	60	26.5	26.3	8.5
Mussel	64	26.5	26.7	10.5
Acadian Redfish	2	27.0	27.0	0.0
Pollock	3	27.0	27.7	2.1
Lobster	247	28.0	29.8	10.4
Scallops	153	30.0	30.3	7.7

Table 3.5A (left) and Table 3.5B (right): Descriptive statistics of price for select seafood types in an appetizer (left) and entrée (right). In both tables, seafood types are listed in increasing mean price and underutilized species are highlighted in green.

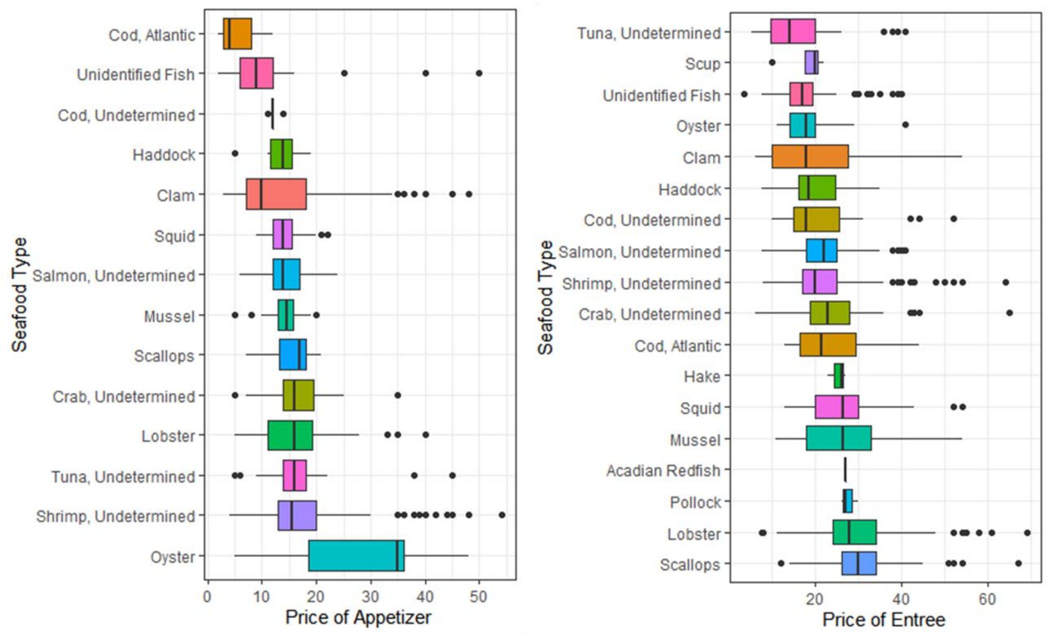


Figure 3.7A (left) and 3.7B (right): Boxplots comparing the prices of select seafood types in appetizers (left) and entrees (right) (in US dollars). Seafood types included are: unidentified fish, all seven underutilized species, unidentified cod and Atlantic cod, and the top ten most frequently occurring seafood types. Boxplots are organized from lowest mean price to highest mean price.

Appetizers that included oysters, unidentified shrimp, and unidentified tuna were generally sold at a higher price (mean price between $17-$30) than appetizers containing other seafood types. Appetizers that included unidentified fish, Atlantic cod, and unidentified cod were generally sold at a lower price (mean price between $6-$12) than appetizers containing other seafood types. Haddock was the only underutilized species that was used in an appetizer and it was found in 11 appetizers. Appetizers containing haddock had the fourth lowest mean price (median =$14, mean=$13.50, ± $4) out of all the seafood types in this comparison (Table 3.5A and Figure 3.7A).

Entrees that included scallops, lobster, and pollock were generally sold at a higher price (mean price between $28-$30) than entrees containing other seafood types. Entrees that included unidentified tuna, scup, and unidentified fish were generally sold at a lower price (mean price between $16-$18) than entrees containing other seafood types (Table

3.5B). Four out of the seven underutilized species were found in entrees. Entrees that included Atlantic pollock, Acadian redfish, and hake sold at higher prices compared to most other seafood types (mean price between $25-$28). Entrees containing haddock were sold at a mid-lower price (median=$18.5, mean=20.1, ± $6) compared to most other seafood types (Table 3.5B and Figure 3.7B)

Seafood Transparency on Popular Menus Items
Harvest Method

Shrimp was found on 64% of menus during both seasons (Table 3.3 and Figure 3.6B). During the summer, three restaurants communicated shrimp as "wild-caught" while the other 92 restaurants did not provide any additional information. In winter, none of the menus communicated if the shrimp was wild-caught or farmed. Similarly, salmon was found on 54% of winter menus and 47% of summer menus (Table 3.3 and Figure 3.6B). In both seasons, over 87% of the menus did not communicate any further information about how salmon was harvested.

Specifying Species / Type

Tuna was found on 52% of winter menus (n=78) and on 57% of summer menus (n=85) (Table 3.3 and Figure 3.6B). During the summer, 54 menus did not communicate the type of tuna offered and 15 more menus offered a mix of unidentified tuna along with tuna listed as "ahi" tuna. For the rest of the summer menus that offered tuna, ahi tuna was offered on 11, yellowfin on 2, bluefin on 2, and albacore was offered on one menu. Winter menus had similar percentages of unidentified and identified tuna offerings as summer menus (Table 3.4).

Crab was found on 30% of winter menus (n=45) and 34% (n=51) of summer menus (Table 3.3 and Figure 3.6B). During the summer, 17 menus did not communicate the type of crab offered on any dishes and 12 more menus offered a mix of unidentified crab along with crab listed as either Jonah crab, king crab, lump crab, Dungeness crab, and snow crab. A total of 15 menus identified all the types of crab on their menu to the seafood type level and five of these menus used more than one type of crab. For these 15 menus that offered crab, jonah crab was offered on six, king crab on five, lump crab on five, blue crab on three, snow crab on one, and peeky toe crab was offered on one menu. Winter menus had similar percentages of unidentified and identified crab offerings as summer menus (Table 3.4).

Sea basses were found on 6% of winter menus (n=9) and 12% of summer menus (n=18) (Table 3.3 and Figure 3.6B). During the summer, two of the menus did not communicate the type of bass offered. For the rest of the summer menus that offered bass, striped bass was offered on nine, sea bass on four, Chilean sea bass on two, and black sea bass was offered on one menu. During the winter, all nine menus communicated the type of bass offered – sea bass was offered on four, black sea bass on three, Chilean sea bass on two, and striped bass was offered on one menu.

Trout was found on 7% of winter menus (n=11) and 5% of summer menus (n=8) (Table 3.3 and Figure 3.6B). During the winter, three of the menus did not communicate the type of trout offered. A total of six menus offered rainbow trout and two menus offered sea trout. Summer menus had similar amounts of unidentified and identified trout offerings as winter menus (Table 3.4).

Salmon was found on 54% of winter menus (n=81) and 48% of summer menus (n=71) (Table 3.3 and Figure 3.6B). While different types of salmon species (e.g. coho, king) were expected on summer and winter menus, only one menu communicated a specific salmon species. A king salmon was offered on one menu during the winter assessment (out of 81 menus that offered salmon) alongside unidentified salmon.

Unidentified fish were found on 25% menus during the winter (n=38) and on 23% menus during the summer (n=35). A “whitefish” description was found on 5% of menus during the summer (n=8).

3.4.2 Current Consumption Messages About Underutilized Species to Consumers

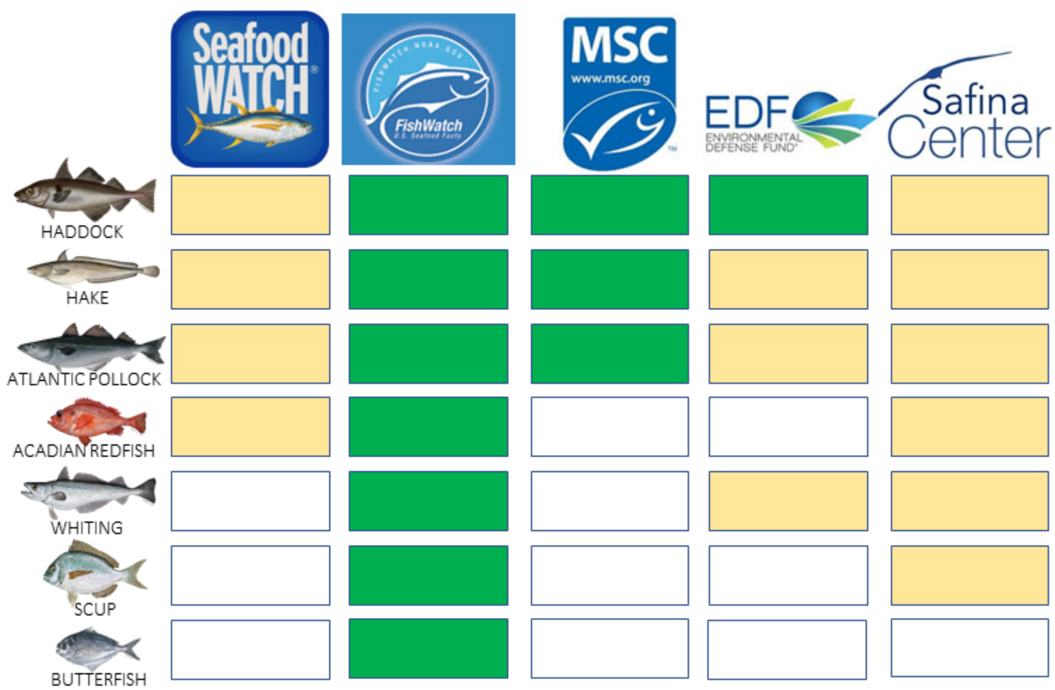


Figure 3.8: Recommendation and ranking of each underutilized species by organization. Colors indicate the recommendation each fish received according to a traffic light scheme. Green represents “Best Choice”, yellow represents “Good Alternative”, and red represents “Avoid”. White shows instances where organization did not provide any type of recommendation for the species.

Organizations did not provide recommendations for all underutilized fish and where recommendations were available, recommendations differed across species (Figure 3.8). Haddock, hake, Atlantic pollock, and whiting were considered either Best Choice or a Good Alternative. Acadian redfish, scup, and butterfish were not included in recommendations from MSC or EDF while butterfish only received a recommendation from Fish Watch. These results suggest that consumers and chefs receive little to no recommendations for several underutilized species and inconsistent recommendations about others, especially Acadian redfish, whiting, and scup (ranked as Best Choice, Good Alternative, and no ranking).

3.5 Discussion

3.5.1 Consumers Access to Seafood and Underutilized Species

Overall, seafood was more abundantly available and there were more seafood choices in seafood restaurants than non-seafood restaurants. While there was a diversity of seafood types available across Boston restaurants in all neighborhoods, the diversity was not evenly distributed across restaurant types in either season. The top 5 most frequently occurring seafood species/types were the same in both seasons - unidentified shrimp, unidentified salmon, unidentified tuna, lobster, and clams. Our results suggest that consumers have limited access to underutilized species in Boston restaurants. Haddock was the most frequently occurring underutilized species on menus, found at ~19% of restaurants and included in ~2% of all seafood dishes. Other underutilized species were found at only ~2% of all restaurants and a fraction of all seafood dishes. As a comparison, Atlantic cod, a popular local fish (which is overfished and is experiencing overfishing in New England), was found at ~25% of restaurants and included in ~2% of all seafood dishes across Boston.

Our results are similar to results from Eating with the Ecosystem’s 2018 Eat Like a Fish citizen science project where citizen scientists visited seafood markets throughout New England to assess the occurrence of different local seafood species (Masury and

Schumann 2019). This study found, apart from haddock, underutilized species were found in less than 10% of markets (white hake and scup were found 9%, redfish 8%, and silver hake 4%, and butterfish 3%). Collectively, results suggest that consumers have limited access to underutilized species in both marketplaces (Masury and Schumann 2019) and restaurants in New England. Therefore, New England consumers likely have difficulty fully participating in the Eat Local Seafood movement, regardless if they eat seafood at home or at restaurants.

3.5.2 Demographics of Restaurants That Offer Underutilized Species

More restaurants offered underutilized species in the winter compared to summer, with haddock being the most widely available option. The eight restaurants responsible for the 12 instances an underutilized species, besides haddock, was offered were a mix of seafood and non-seafood restaurants spanning across price ranges and neighborhoods. One aspect that all these restaurants appear to have in common was a more limited menu (fewer dishes offered overall). Further analysis shows that during the winter assessment, these eight restaurants offered a median of 11 appetizers and 9.5 entrees, while the restaurants that did not offer underutilized species had a median of 13 appetizers and 27 entrees. Therefore, underutilized species may be best suited for restaurants that offer a relatively small menu.

According to several business advice articles targeted to restaurant professionals, a smaller menu can be a strategic business choice that simplifies and improves operations. A smaller menu allows cooking staff to focus on producing a few quality and consistent dishes rather than a vast number of dishes. A smaller menu also helps restaurants reduce inventory and therefore reduce food waste and increase profit margins.

Restaurants that regularly change their menu because they offer seasonally available foods benefit from smaller menus because of lower menu printing costs (Mealy 2018, Mealy 2019, Aaron Allen 2020). In response to an emerging issue in recent months, restaurants may be reducing their menu due to the novel challenges posed by the COVID-19 pandemic. Limited menus widen profit margins by mainstreaming inventory and reducing staff requirements without having to increase consumer prices (Wienner-Bronner 2020). Moving forward, underutilized species may be especially appealing to restaurants that operate with a smaller menu as it may indicate the restaurant values seasonal local foods, quality dishes over quantity of dish choices, and food items with a high profit margin.

3.5.3 Potential Tools for the Eat Local Seafood Movement and Underutilized Species

Results show that popular seafood recommendation tools did not provide adequate or consistent recommendations for New England's underutilized species. Moving forward, leaders within New England's seafood industry and the Eat Local Seafood campaign may want to align efforts to build upon existing resources, or create new resources, so New England's regional species are better represented, and consistent recommendations are broadcasted to chefs and consumers.

Seafood recommendation guides are just one type of resource that can influence seafood purchase decisions. Other types of resources that could increase restaurant and consumer involvement in the Eat Local Seafood campaign are mobile apps showing seafood seasonality or access to local seafood at restaurants and markets, loyalty card programs, or cookbooks focused on lesser-known species and preparations such as Simmering the Sea from Eating with the Ecosystem (Schumann, Masury, and Rochett

2018). Consumers have indicated that printing sustainability rankings on menus, showcasing information on restaurant websites, and sharing sustainability efforts being undertaken by businesses on social media may also influence seafood purchasing decisions, especially with Millennials (National Restaurant Association 2018b).

While they are well-intentioned, some ecolabels and suggestion guides have been known to create confusion and mistrust within some seafood industries and with some consumers (Jacquet and Pauly 2007; Seaman 2009; Roheim 2009; Hallstein and Villas-Boas 2013). Moving forward, future communication efforts could avoid these issues by focusing on consistent and regionally relevant recommendations for a species, transparent explanations for arriving at a recommendation, and demonstrate industry collaboration and trust among decision-makers. Therefore, future research should explore which regional groups of individuals (fishermen, chefs, scientists, etc.) and which types of resources chefs and consumers find reputable and trustworthy

The Gulf of Maine Institute's "Responsibly Harvested" brand is one example of a regionally focused resource in the form of an ecolabel. This ecolabel identifies fish that can be traced to being harvested from the Gulf of Maine. The ecolabel further verifies that the stock has a management plan, there is sufficient data to determine harvest levels, harvest levels are being monitored, and enforcement exists to prevent illegal practices and unreported harvest (GMRI 2010). The "Gulf of Maine Responsibly Harvested" brand has verified that five out of seven underutilized species are eligible for the ecolabel: Acadian redfish, Atlantic pollock, white hake, silver hake, and haddock (GMRI 2020b). Butterfish and scup may not be eligible for the ecolabel since they are mid-Atlantic managed species and most of their population is located in areas south of the

Gulf of Maine; currently, there is also low effort for these species in the Gulf of Maine. The "Responsibly Harvest Brand" ecolabel is an example of resource that provides a clear recommendation, transparency, and demonstrates collaboration among New England's seafood industry professionals, scientists, and marketplaces (GMRI 2020a).

3.5.4 Pathways For Future Eat Local Seafood Campaign Efforts

An in-person campaign or other approach may be more effective at recruiting restaurants to incorporate more underutilized species into their restaurants than new or updated print or online resources. For example, interest in underutilized species may increase when chefs are directly engaged about the level of support they can offer to their local fisheries through their restaurant's food purchases or how their menu options influence which seafood types customers purchase for cooking at home (Miller et al. 2012). Another attractive selling point could be communicating how underutilized species may align with chefs' and customers' interest in sustainability and reducing food waste. According to the 2018 Sustainability Report, over 55% of consumers say they consider a restaurant's food waste-reduction efforts an important factor when they choose a restaurant to eat at (National Restaurant Association 2018b). Also, underutilized species may be more attractive to chefs and restaurant owners when they observe the profit potential. Underutilized species are inherently low-value fish, but the seasonal menu assessments provided in this study, and related literature suggest that underutilized species can successfully be sold at the same high price point as popular species (Shamshak et al. 2019). On average, entrees that included Atlantic pollock, Acadian redfish or hake sold at higher prices compared to every other finfish seafood type available at Boston restaurants in 2019. Preparing and selling low-value underutilized species, especially as a whole fish versus a fillet, is an effective way a restaurant can make their menu distinct from other menus, support their local fisheries, reduce food waste, and realize a high profit margin.

Switching from imported catch to local catch of the same species is one easy step restaurants can make to support local seafood and reduce their overall carbon footprint. Despite haddock being a locally harvested species, most haddock found on Boston menus is likely imported. In 2018, the U.S. landed 6,557 metric tons of haddock and imported 20,224 metric tons of haddock from other countries such as Norway and Iceland (NMFS 2020). While there is great potential in substituting domestic haddock for imported haddock, current fishing regulations make it challenging to increase domestic haddock landings because they are frequently caught with Atlantic cod in the Gulf of Maine. Atlantic cod is considered a regional “choke species” for haddock and fishermen have reported that they have lost money when they catch Atlantic cod (LaCasse 2018). A clear ecolabel specific for New England–caught haddock may be embraced by chefs and consumers; however, fishermen could lose profit potential if the choke species issue is not addressed by regulation changes or more selective fishing gear (DeCelles et al. 2017).

Cod was also found on many restaurant menus. Like haddock, most cod dishes are likely composed of imported Atlantic cod from Europe or Pacific cod instead of locally harvested Atlantic cod. While sourcing local Atlantic cod may not be desirable due to overfishing and fishing regulations, there are other fish, including Atlantic pollock and hake, that yield large fillets, have bright white colored flesh when cooked, and a mild flavor that are very similar to Atlantic cod. An important topic to investigate further is how consumers respond to fish with similar flavor profiles but different sustainability characteristics. Results from such studies would help evaluate if there are locally harvested and abundant species that have potential with consumers and could replace overfished or imported whitefish species on restaurant menus.

3.5.5 Study Limitations, Improvements, and Future Research

The results presented here indicate the types of seafood, the level of transparency, and the level of diversity one could expect to observe on menus during the summer and winter at many Boston restaurants. However, these results may not have fully captured the Boston's seafood availability throughout the year at all restaurants

Results likely underestimate the presence and abundance of certain seafood items. Scrod is technically a name for either cod or haddock. Since we gave scrod its own category, the %FO for cod and haddock are likely underestimated. These methods did not capture daily specials that may have been listed inside the restaurant or verbalized to the customers. Therefore, it is possible that certain species – including butterfish and whiting - were offered at restaurants either as the "Fish of the Day", as "whitefish", or were part of a dish special that the online menu did not include. Results also likely do not represent the presence, abundance, and diversity of seafood at ethnic or sushi restaurants as these types of establishments were excluded due to their potential to be outliers in the assessments. Results also likely underestimated the degree that Atlantic salmon was written on restaurant menus since the menu review was focused on finding the names of wild-harvested salmon species.

Additionally, this study did not determine the extent seafood transparency information was available to consumers in other forms. A restaurant employee may be able to determine and verbally communicate the harvest method (farmed vs. wild-caught) or species (yellowfin tuna vs. bluefin tuna) if asked by a customer. Reformatting this study to use a citizen scientist approach like that used by Eating with the Ecosystem (Masury and Schumann 2019) would address this limitation because citizen scientists would be encouraged to ask restaurant staff for clarifications about seafood items/types.

This assessment was conducted for many reasons, including providing seasonal snapshots of seafood availability in Boston that could help document future changes and shifting norms. Moving forward, this database could also be used to assess the effects of the recent COVID-19 pandemic on seafood offerings in restaurants. For example, this database could assess the extent restaurants: 1) permanently close, or 2) change their seafood offerings in response to COVID-19. Restaurants may be more willing to support local fishing industries because local seafood may be more reliable than imported seafood, safer, or restaurants may want to support local food communities that were also highly impacted by COVID-19. On the other hand, restaurants may withdraw from using some seafood offerings because they may not be suitable for “carry out only” dishes. As of July 3, 2020, of the eight restaurants that offered underutilized species, seven are open. Of the seven, two restaurants are using outdoor dining areas and the rest are serving food to go. All seven restaurants are offering some seafood options on their menus. Acadian redfish and haddock were being offered at separate restaurants, both in fried fish and chips dishes.

This study used restaurant menus to capture the extent different types of seafood, including all seven underutilized species, were being served in Boston restaurants from 2018-2019, and describes the depth of seafood transparency customers received about popular seafood items. Well-known seafood suggestion tools were also examined for their ability to provide adequate information about New England's underutilized species. Results suggest that these seafood suggestion tools did not provide adequate or consistent recommendations about each underutilized species and, except for haddock, restaurants rarely offered underutilized species. It could be advantageous for New England's seafood industry professionals to collaborate with Boston restaurants to identify if underutilized species have marketplace potential as seafood sustainability and sourcing local seafood continues to be a trend in U.S. restaurants during the sustainable seafood movement.

CHAPTER 4

SOMETHING TO TALK ABOUT: EVALUATING AND TESTING MILLENNIALS AND GEN-ZERS. EXPERIENCES WITH NEW ENGLAND SEAFOOD

4.1 Abstract

Marketplace activism is increasingly being called-on as a bottom-up approach for sustainable marine resource use; however, little is known about how the generation, and upcoming generations, with the largest purchasing powers (Millennials and Generation Z) view, perceive, and engage with their local seafood options. Here, we use two online surveys, and a sensory experiment, to explore and test how these generations engage with New England seafood. Results reveal that these populations: 1) are highly unaware of the names and flavors of their local seafood options but that they want to be more engaged, 2) find the taste and other sensory qualities of several underutilized species to be on par with those of Atlantic cod, and 3) wanted to share both their positive and negative fish eating experiences with friends and family. The results and insights from the sensory experiment and online surveys could be used to improve marketing campaigns and marketplace activism for New England seafood.

4.2 Introduction

There have been growing calls for Americans to eat more domestically caught and raised seafood. Over the past few decades, American seafood consumption has remained stagnant between 15-16 pounds per capita, significantly lower than the global average (~ 42lbs/year) (NMFS 2018), and less than one-third of Americans regularly meet the United States Department of Agriculture's (USDA) health recommendation of two servings of seafood each week (Storey et al.,2006, Hicks et al. 2008; Getchis et al. 2020; Richard and Pivarnik 2020). Additionally, Americans have shifted their seafood consumption away from wild domestic and farmed seafood towards primarily imported farmed and wild-caught species, most notably farmed shrimp, farmed salmon, and tuna (Potera 2018, Shamshak et al. 2019). Fishing communities have urged consumers to eat more domestic seafood to bolster support for American fishermen as they face a growing list of economic hardships. Two economic hardships that have created a challenging negative feedback loop are: 1) domestic catch devalued by imported seafood with high carbon footprints, and 2) increased financial stressors associated with fishing in a changing climate (Keithly et al. 2006; Hudson and Peros 2013; Mills et al. 2013; Stoll et al. 2015). In New England, increasing landings with a diversity of marine foods is one strategy that has been shown to support sustainability goals and create resilience for fishing industries in a changing climate (Young et al 2019). Evaluating how to enhance consumers' engagement and relationship to a diversity of species – such as the underutilized species identified in Chapter 2 - is a progressive step towards helping New England's seafood industry strategize and build more adaptive and sustainable markets in a changing climate.

Online surveys, fishing reports, willingness to pay (WTP) experiments, and even sensory assessments have gathered important insights about American consumers' engagement with seafood and sustainability. Sustainable seafood tools such as seafood suggestion guides and ecolabels have increased consumers' concerns about seafood and have influenced personal and large-scale purchasing decisions (Kemmerly and Macfarlane 2008; MSC 2018; Whole Foods 2020). American consumers are especially drawn to labels that highlight a specific region (Fonner and Sylvia 2014; Richard and Pivarnik 2020) and have shown a greater willingness to pay for seafood items marked with a regionally-focused label (Fonner and Sylvia 2014; Brayden et al. 2018; Tian et al. 2019; Getchis et al. 2020). Sustainability, origin, flavor, safety, and quality (as indicated by freshness, smell and appearance) have all been ranked as very important determinants of seafood choice in several studies (Fonner and Sylvia 2014; Getchis et al, 2020). Additionally, point of sale, family and friends, health newsletters, "media", and cookbooks are top places to get information about seafood (Hicks 2008; Richard and Pivarnik 2020).

Sensory assessments have been conducted with seafood to challenge widely held consumer beliefs that can influence purchasing decisions and therefore marine resource use (Condrasky et al. 2005; Banse 2019; Rasor 2017). Results from these seafood sensory assessments have helped the seafood industry identify, test, and challenge consumer biases that can restrict fishing activities. . So far, results from sensory assessments have helped domestic seafood industries navigate the marketplace potential of frozen seafood vs. "fresh" seafood (Banse 2019; Rasor 2017), and domestic vs. imported shrimp (Condrasky et al. 2005). One important note about these studies was that most of the participants were 40 years old or older at the time of the study (Storey et al. 2006, Hicks et al. 2008; Rasor 2017; Tian et al. 2019; Getchis et al. 2020; Richard and Pivarnik 2020).

The Millennial generation (those born between 1981-1996) and Generation Z (e.g. Gen-Zers) (those born in 1997 or after) have been largely left out of surveys and sensory assessments, or at least, have not been the explicit focus of recent research. Conducting sustainable seafood research with younger generations is critical, especially with Millennials, since they are the largest living generation, largest generation in the U.S. labor force, and have just become the largest purchasing power of any generation (Conley 2018; Fry 2020). Research on Millennial food purchasing and consumption behavior suggest they behave differently than older generations. For example, Millennials are increasing their consumption of protein sources and decreasing the amount they spend on frozen and prepared meals (Conley 2018); they tend to seek out information before making purchasing decisions (Barber, Dodd, and Ghiselli 2008), and may have diets more aligned with federal dietary recommendations (Kuhns and Saksena 2016). Millennials also tend to dine out 30% more often than older generations (Kuhns and Saksena 2016) and appear more aware and concerned about climate change (Funk and Tyson 2020), which is highly related to the sustainable food production and consumption conversation. While there is limited research on Gen-Z, the Pew Research Center has found that Gen-Z and Millennials hold many similarities (Parker and Igielnik 2020). These differences from older generations suggest that results from the previously mentioned seafood studies may be outdated or do not apply to these younger generations.

Marketplace activism is increasingly being called upon as a bottom-up approach for sustainable marine resource use; however, little is known about how Millennials and

Gen-Zers view, perceive, and engage with their local seafood options. Here, we explored and tested how Millennials and Gen-Zers in New England have engaged with local seafood through four assessment components: 1) an initial online survey, 2) a blind sensory session, 3) an informed sensory session, and 4) a post-sensory online survey. Results are expected to improve understanding of how individuals within the Millennial and Gen-Z generation engage with New England seafood. In addition, we evaluate marketplace potential for several underutilized species identified in Chapter 2 to provide novel insights in support of improving marketing campaigns and marketplace activism for the New England seafood industry.

4.3 Methods

An initial online survey, the two-part sensory experiment (blind and informed sessions), and a post-sensory online survey were conducted at the University of Massachusetts Amherst in partnership with the Department of Food Science and UMass Dining Services. UMass Dining is a nationally recognized, award-winning program that serves over 6 million meals a year to the University community of over 30,000 people. In recent years, UMass Dining has prioritized increasing food purchases from New England producers to meet their food sustainability goals (e.g. The Real Food Challenge 2020). UMass Amherst was an ideal location to conduct this study for several reasons. The University community is largely composed of individuals from the Millennial and Gen-Z Generations, and the community is highly engaged with local foods, in part because of UMass Dining's sustainability goals. In addition, almost 80% of undergraduate students are Massachusetts residents and therefore can represent New England consumers from Gen-Z. UMass Dining was also interested in how New England seafood can help them meet their food sustainability goals and how UMass purchasing power could support local fisheries

The target population of this study was individuals at the University of Massachusetts Amherst who were born between 1980 – 2000 (18 – 38 years old). Persons within that age range could participate providing they: 1) did not have any food allergies or sensitivities, and 2) were an active seafood consumer (ate seafood at least 1x/month). Recruitment for the initial online survey, subsequent sensory experiment and post-experiment survey, took place from Monday September 30th 2019 to October 8th 2019. The tasting experiment took place on October 8th and October 10th 2019 at the Hampshire Dining Commons. Fliers, social media, university email lists, and opportunistic intercept sampling were used to recruit panelists. Additionally, individuals who entered the dining commons were recruited to participate in the survey and sensory tests when space was available during the tasting sessions.

4.3.1 Initial Online Survey

The initial online survey included closed- and open-ended questions. This questionnaire explored the same topics as previous surveys (Storey et al.,2006, Hicks et al. 2008; Getchis et al. 2020; Richard and Pivarnik 2020) including current consumption and purchasing behavior, awareness, and sustainability. Original topics in this survey included childhood experience with seafood, familiarity with certain seafood types, engagement with New England seafood, and views about New England's seafood industry and extreme weather (Table 4.1). Where appropriate, survey items were randomized to avoid order effects. Questions about the threats of "extreme weather" were asked because the primary way most people have experienced climate change has been through extreme weather events (USGCRP 2018). These questions were adopted from the Gallup World Poll, but the term “extreme weather” replaced “climate change”. The term “extreme weather” was also used instead of climate change to reduce unfamiliarity and negative attitudes that have emerged when “climate change” terminology has been used in past studies (Lee et al. 2015; Pew Research Center 2016). Extreme weather, however, may be more relatable for individuals located in New England, a region highly affected by extreme weather events (as well as climate change) (USGCRP 2018).

The initial online survey was also used as a recruiting and screening tool for the subsequent sensory sessions. The survey was validated for content and pilot tested by nine consumers prior to being implemented.

All respondents completed the online survey using a personal device (phone, tablet, computer). The survey was hosted on Qualtrics and took approximately 15-20 minutes to complete. All respondents who completed the initial survey were entered into a raffle to win one of three $50 Amazon gift cards. The study was approved by the University of Massachusetts Institutional Review Board (Protocol ID: 2019-5725).

4.3.2 Sensory Experiment

The sensory experiment was conducted in two sessions: 1) a blind sensory session, and 2) an informed sensory session. This experiment tested for a “name effect” or name bias by evaluating if panelists changed their ratings for sensory characteristics when they either did and did not know the name of the fish being consumed. The name effect was tested with a sensory experiment because many white-fleshed fish (e.g. “whitefish”) have different levels of demand from consumers and different sustainability characteristics yet seem to have similar flavor profiles. Changes in appeal ratings or consumption ratings for certain fish over the four assessment components of this study were also assessed to identify if tasting a fish type changed panelists' perceptions or consumption intentions.

The sensory experiment took place at the Hampshire Dining Common in a meeting room arranged to provide a semi-private controlled sensory assessment. Panelists randomly sampled three underutilized fish (white hake, Atlantic pollock, and haddock), a fish of interest (dogfish) and a popular fish that is currently overfished in the Gulf of Maine region (Atlantic cod). These fish were chosen because they were consistently available at the Boston Fish Pier at the time of the study and would allow comparisons among different whitefish with different sustainability characteristics. Dogfish is the only fish that was delivered as a frozen product because almost all locally caught dogfish is sold frozen because of regulations in Massachusetts (Wiersma and Carroll 2018). At the time of the study, UMass Amherst was one of the largest purchasers of dogfish in the state, UMass Dining prepared dogfish as fried whitefish on Fridays in the dining commons, and was interested in collecting more formal responses about dogfish from consumers.

The panelists sampled these six fishes on two separate days. On the first day, fish samples were labeled with a three-digit blinding code and panelists tasted and rated all fish without knowing the name of the fish (i.e., "blind"). On the second day, the same panelists repeated the tasting session and rating protocol, however this time the name of each species was provided prior to tasting (i.e., "informed"). Panelists cleansed their pallet in between samples by sipping water and waiting at least one minute.

Each sensory session was expected to take less than 30 minutes to complete. Panelists scored the following attributes for each sample on a 9-point hedonic scale ranging from “dislike” extremely, to “like” extremely: appearance, texture, smell, and taste. Overall appeal was scored on a 5-point hedonic scale from “poor” to “excellent” with a sixth point of “I don’t know”. Interest in ordering the fish at both a restaurant and at a UMass Dining facility (e.g. consumption intentions) was scored on a 5-point hedonic scale from “definitely not” to “definitely”.

Panelists received instructions and answered questions on a tablet within their own tasting booth. All aspects of the sensory tests were conducted using Compusense. Figure 4.1A and Figure 4.1B show the evaluation panelists completed for each sample through Compusense. Panelists who completed both sensory sessions were compensated with their choice of either a $10 Amazon gift card or a meal voucher to the UMass Dining Commons.

Fish Sample Preparation

On both days, fish samples were prepared to be as uniform as possible. Samples were steamed so panelists could evaluate species in their most unaltered state. The following preparation protocol was chosen because the dining hall chefs and investigators felt it provided the most consistent results compared to other previously tested preparation approaches.

Fish fillets were sourced from purveyors at the Boston Fish Pier and delivered to the Hampshire Dining Common the day before the tasting session by Berkshore (a seafood distribution company). During the morning of the sensory session, all fish fillets were evaluated for quality, blotted with paper towels to remove excess moisture, and cut into nearly identical square sub-samples that weighed between 0.8-1.2 ounces. Between 9 – 12 samples of the same fish species were placed in 12” x 10” x 3” pans that were labelled with the fish type, wrapped in plastic wrap, and kept cool until final preparation. Just prior to steaming, pans were unwrapped, and 1/8 tsp of flaked salt was sprinkled evenly across all fish samples in each pan. Then the pan was tightly rewrapped with plastic wrap. One pan of each fish type was placed in a combi-oven for approximately seven minutes, which allowed time for the samples to cook to temperature with its own moisture and reach the approved temperature of 145°F without overcooking. Pans were then removed from the oven and quickly brought to the sensory room and placed in labelled warm chaufing dishes. Chaufing dishes were located behind a wall so panelists could not see the fish labels. To maintain consistency and freshness, a newly prepared set of fish samples replaced the previous set of samples every 10 – 15 minutes

4.3.3 Post Experiment Survey

A post-sensory experiment survey evaluated: 1) if panelists from the sensory sessions changed their perceptions of different fish over the course of the study, 2) if they would recommend the fish to a friend or family member, and 3) if they shared their experience with family or friends (e.g. created social influence). Recommendations were recorded on a five point scale from “definitely not” to “definitely” with a sixth point being “not sure”. Panelists had the option of describing the type of experience they shared with their family or friend in an open answer response. Another open answer response was available for panelists to describe if they changed their perceptions about any species after participating in the study (Table 4.2).

All panelists that completed both tasting sessions were asked to complete the online post-sensory survey that was hosted on Qualtrics. The survey took ≤10 minutes to complete. Panelists did not receive any additional incentive for completing the post-sensory survey.

4.3.4 Statistical analyses

Initial and Post-Sensory Online Surveys

Descriptive statistics (frequencies, percentages, means, and standard deviations) were conducted to provide an overall summary of the initial and post-sensory online surveys responses. The *tm* package (Ingo and Hornick 2019), *SnowballC* package (Bouchet-Valat 2020) and *wordcloud* package (Fellows 2018) in R were used to text mine and generate word clouds from the panelists' written responses about the types of seafood dishes they consumed while growing up. These analyses helped identify frequently occurring seafood types and preparation styles within all panelists' open responses. In the post-sensory survey, written responses about perceptions of specific species were reviewed and grouped into positive or negative responses based on species and then group totals were counted.

Responses about overall rating and consumption intentions (at UMass and a restaurant) from the initial survey (Table 4.1) and post-sensory online survey (Table 4.2) were scaled and used as variables in Bayesian models in conjunction with responses from the same questions in the sensory experiment (Figure 4.1A and Figure 4.1B).

Sensory Experiment

The sensory experiment was designed to test for a "name effect". If a name effect was detected, then the consumer's awareness with the fish's name could have influenced how they rated their experience eating the fish (e.g. a bias exists). This is important because if there are biases based on the fish's name, rather than actual taste and experience, this could affect consumer demand for whitefish with similar flavor profiles but different sustainability characteristics.

Multilevel regression models were used to estimate effects. Weakly informative prior distributions were used to calibrate the models without strictly constraining the models' ability to explore the parameter space. All priors were assigned using Gaussian distributions. Additional information about these priors can be provided upon request.

Name Effect

The multilevel Name Effect model had the following structure:

$$Rating \sim Wave + (1|IDNumber) + (1+Wave|Item) + (1+Wave|Fish)$$

Rating was the outcome of the Name Effect model. Rating is a vector of all five ratings for all five fish types at both waves across all panelists. Wave is dummy-coded variable that indicated which of the four assessment components of the study produced the ratings. Here, ratings were produced from the blind sensory session (Wave 2) and informed sensory session (Wave 3). IDNumber was a categorical variable that identified which ratings belonged to each panelist. Item was a categorical variable that identified ratings associated with each appeal item (texture, flavor, etc.). Fish was a categorical variable that identified ratings associated with each of the six fish species.

The notation *(1|IDNumber)* specified that the intercept of the model could vary for each panelist, thus allowing appropriate estimation of the effect of Wave across each panelist. The notation (1+Wave|Item) allowed both the model intercept and the slope of

Wave to vary across each five appeal ratings. The notation (1+Wave|Fish) allowed the intercept and slope of Wave to vary across each of the 5 fish types.

Wave Effect

The multilevel Wave Effect model takes the form of:

$$\text{Rating} \sim \text{Wave} + (1|\text{IDNumber}) + (1+\text{Wave}|\text{Item}) + (1+\text{Wave}|\text{Fish})$$

Another goal of this experiment was to identify if panelists' ratings for each fish changed across the four assessment components (i.e., repeated measures): –initial online survey (Wave 1), blind sensory session (Wave 2), informed sensory session (Wave 3), and post sensory survey (Wave 4).

In the Wave Effect model, rating was the outcome and reflected a vector of ratings for the three items that assessed overall appeal and consumption interest at UMass and at restaurants. Wave was a factor variable that represented the four assessment components of the entire study. Wave 1 was the baseline, and each parameter estimate was a comparison to this baseline (i.e., Wave 2 vs. Wave 1, Wave 3 vs. Wave 1, etc.). The exact same prior specifications were used for this model as the Name Effect model, except the prior on the intercept was rescaled to accommodate the ratings on 5-point scales instead of 9-point scales.

Seafood Consumption Effect

Finally, we tested whether panelists' pre-existing fish consumption habits influenced "Name Effect" and "Wave Effect". The measure of fish consumption frequency from the initial online survey was added to the Name Effect model and Wave Effect model as an interaction with the wave and name parameters. All panelists in the taste test ate fish occasionally (once a month) to fairly frequently (two or more times per week). Therefore, we cannot analyze whether those with little to no fish consumption exhibit different response patterns. Data were standardized by calculating z-scores (Mean = 0, Standard Deviation = 1) prior to analyses to reduce multicollinearity in the interaction terms.

The Name Effect with Consumption interaction model was fit identically to the Name Effect model and used the same prior distributions. The structure of the Name Effect with Consumption model was:

*Rating ~ Wave*Consumption + (1|IDNumber) + (1+Wave|Item) + (1+Wave|Fish)*

The Wave Effect with Consumption interaction model was fit identically to the Wave Effect model and used the same prior distributions. In this model, Rating and Wave reflected the vectors described for the "Wave Effect" model. The structure of the Wave Effect with Consumption model was:

*Rating ~ Wave*Consumption + (1|IDNumber) + (1+Wave|Item) + (1+Wave|Fish)*

If there was an interaction effect, a leave-one-out cross-validation was conducted. Results of a leave-one-out cross-validation (Vehtari, Gelman, & Gabry, 2017) between the interaction model and a model with fish consumption without an interaction identified if inclusion of the interaction term was more suitable than non-interaction terms alone.

4.4 Results

4.4.1 Initial Online Survey

A total of 254 responses to the initial online survey were received with a 65.3% completion rate (N=166) and a median completion time of 16.5 minutes. A total of 31 respondents (18.7%) wanted to complete only the initial online survey. A total of 135 panelists (81.3%) completed the survey with the intention of signing up for the tasting session but only 103 qualified to participate, and 61 ultimately participated in both the blind and informed tasting sessions. Social media and email recruited the most panelists (n=141), followed by QR code on posters (n=14) and intercept method (n=11). Since this study focuses on the sensory experiment, the descriptive and inferential results reported hereon focus on the subset of panelists who completed the survey and completed the sensory experiment (unless otherwise noted).

Demographics

Basic demographic characteristics are shown in Table 4.3. More than 50% of panelists grew up in Massachusetts. There was an almost even split between gender and generation.

Past and Current Experience

Panelists' childhood experience with seafood was very similar to their current engagement with seafood. Over 70% of panelists recalled eating seafood a few times per month to at least once per week while growing up, and over 80% of panelists stated they currently eat seafood a few times per month to at least once per week (Table 4.3). Panelists mentioned tuna, salmon, and shrimp most often when they described the seafood dishes they ate while growing up (Figure 4.2). Similarly, panelists reported that out of 27 possible seafood choices offered in the survey they currently eat tuna, farmed salmon, and farmed shrimp most often (Table 4.3).

Panelists noted that their current experiences with seafood primarily consisted of consumption in sit-in restaurants (43%) followed by home preparation (39%).

Familiarity

Panelists' familiarity with 27 different types of seafood varied (Figure 4.3). Over 90% of panelists had both heard of and tasted wild salmon, lobster, tuna, clams, scallops, cod, and squid. Out of all fish choices in the initial survey, cusk, a relative to Atlantic cod, was least familiar to consumers in both name (5% heard of) and taste (0% tasted). Except for haddock, panelists were not familiar with the underutilized species presented in Chapter 2. A total of 92% of panelists had heard of haddock and 82% had tasted it. Pollock and dogfish were somewhat familiar to panelists (75% have heard of them); however, more panelists had tasted pollock (48%) compared to dogfish (16%). Panelists were less familiar with Acadian redfish (43% heard of, 16% tasted), hake (44% heard of, 15% tasted), scup (28% heard of, 8% tasted), and butterfish (25% heard of, 11% tasted) (Figure 4.3).

Perceptions & Behavior

Fish species received a broad range of ratings for appeal and consumption intentions (at UMass and at a restaurant. These ratings are further discussed later in the chapter. One question evaluated panelists' openness to a new culinary experience. Overall, 78% of panelists responded they were more likely than unlikely to order a seafood item at a restaurant that they have never tried before (Figure 4.4).

Name Preference

There was an even split between market name preference for Acadian redfish/ocean perch. Since no panelists stated "neither" and 26% stated "no preference", both Acadian redfish and ocean perch appear to be acceptable market names. Sea bream was preferred more (44.3%) than porgy (14.8%) and scup (18.0%). Dogfish (44.3%) was preferred more than cape shark (32.8%); however, almost 10% of panelists did not like either name, and 11.5% had no preference (Figure 5).

Trust, Sustainability and Purchasing

Almost all of the panelists agreed with our defintion of sustainable seafood - 60 panelists (98%) either agreed or strongly agreed with our defintion and one panelist somewhat agreed with our definition of sustainable seafood (Table 4.1).

A total of 73% panelists (n=45) either ‘rarely’ or ‘sometimes’ sought seafood sustainability information before making a seafood purchase; however, 84% (n=51) are interested in learning about seafood sustainability “a fair amount” or “a lot” more (Figure 4.6A and Figure 4.6B). Nonprofit organizations, state government, and fisheries scientists were the sources they trusted mostly or completely. Delivery drivers, grocery stores, and family/friends were not considered as trustworthy as other sources of seafood sustainability information (Figure 4.7A).

Out of twelve possible attributes, taste, price, and health benefits were the top 3 attributes most frequently rated as “very important” or “extremely important” when evaluating which seafood item to eat. Familiarity, a value-added product, and catch method were less important seafood attributes to panelists (Figure 4.7B).

Panelists were asked to reflect on their recent seafood purchases and determine how much business their seafood purchases provided to New England fishermen. A total of 46% of panelists (n=28) felt their seafood purchases provided no business to very little business to New England fishermen (Figure 4.8A). Approximately 50% said they could realistically provide “a fair amount more” or “a lot more” business to New England fishermen in the future while 11% were not sure (Figure 4.8B).

When asked the question about their level of agreement to “Currently, fish populations in New England are sustainably managed”, 36% (n=22) stated they neither agree nor disagree and 46% (n=28) either disagreed or somewhat diagreed. When asked “how much does each group need to change in order for the seafood industry to reach peak sustainability?”, the majority of participants assigned consumers, management, and grocery stores (84%, 79%, and 64% of panelists, respectively) as the groups that needed to change the most (Figure 4.9).

Self-Acknowledgement

Towards the end of the survey - after panelists had received a substantial amount of information about sustainable seafood and New England’s local seafood- panelists were asked self-acknowledgement questions about their engagement and access to local seafood. A description of local seafood was provided (Table 4.1). Only 25% of panelists somewhat to strongly agreed that they knew a lot about their local seafood options. Roughly the same percentage felt they ate a large variety of wild-caught local seafood. Less than 50% of panelists felt they had access to a large variety of local seafood in restaurants (Figure 4.10).

Extreme Weather

Many panelists were unaware about extreme weather despite being provided examples (Table 4.1). Overall, 55% (n=34) of panelists agreed or strongly agreed that extreme weather events occur in New England, and 54% (n=33) agreed or strongly agreed that extreme weather events are increasing in intensity. Fewer panelists (45%, n=26) agreed or strongly agreed that extreme weather events are occuring more frequently (Figure 4.11A).

Panelists rated how serious of a threat extreme weather events are to fishermen, wild fish populations, and to themselves and their family. Even though only 55% of panelists acknowledged that extreme weather events occur in New England (Figure 4.11A), 69% of panelists (n=42) felt extreme weather events were a serious or very serious threat to fishermen (Figure 4.11B). More panelists felt extreme weather events posed more serious threats to wild fish populations (52% of panelist, n=32), than to themselves and their family (28% of panelists, n=17).

Identities

We asked four identity questions. A total of 98% of panelists consider themselves consumers of seafood. Some of our participants identified themselves as anglers (16%, n=10), activists (39%, n=24), and a majority of panelists identified as environmentalists (73%, n=45).

4.4.2 Sensory Experiment and Post Experiment Survey

Out of the 93 panelists that signed up to participate in the tasting experiment, 61 panelists (66%) completed both days. All but 2 panelists completed both of their sensory sessions within 30 minutes. The ratings from the 61 panelists were evaluated in the Name Effect model and Name Effect with Consumption model. Out of the 61 panelists, 46 panelists (75%) completed all four assessment components of the study (initial survey, blind session, informed session, post tasting session survey). The ratings from these 46 panelists were evaluated in the Wave Effect model and Wave Effect with Consumption Model.

Over the entire study, haddock was the most positively rated fish while dogfish was the least positively rated. The most positively rated sensory characteristics were taste and texture while aroma was the least positively rated characteristic. A small name effect was detected, likely driven by frequent fish consumers who tended to provide higher ratings overall. The models did not detect any significant changes in ratings across the entire study.

4.4.2.1– Name Effect

Panelists in the informed session yielded more positive ratings than the blind session by about 0.23 points on the 9 -point scale. This effect was small in magnitude and there was some uncertainty (Table 4.6). The overall name effect was consistent across each fish type and each sensory characteristic (Figure 4.12-Figure 4.16).

Cod was the most positively rated fish type while dogfish was the least positively rated fish type across the two sessions. The most positively rated sensory characteristics were taste and texture, while aroma was the least positively rated characteristic (Figure 4.12-Figure 4.16).

There was limited support for a name bias across the blind and informed sensory sessions as evidenced by a lack of variation in slopes across fish type and taste ratings (Table 4.6).

4.4.2.2– Wave Effect

There was no evidence that ratings of overall appeal and consumption interest varied across the entire study. The only noticeable variation across each assessment component was during the blind sensory session when ratings declined slightly from the initial survey and then rebounded in the informed sensory session. Ratings between the initial online survey and post sensory survey were almost identical (Table 4.7) (Figure 4.17-Figure 4.18b)

Overall appeal was rated slightly lower than consumption interest at a UMass facility or at a restaurant. Haddock was the most positively rated fish overall, while dogfish was the least positively rated fish (Table 4.7). Unfortunately, we cannot make definitive conclusions about Atlantic cod across the entire study because ratings for cod were not collected in the post-sensory online survey.

4.4.2.3– Influence of Seafood Consumption

There was no evidence for a consumption interaction across the entire study (Figure 4.20) (Table 4.9).

There was small interaction effect between consumption frequency and the name effect (Figure 4.19) (Table 4.8). Panelists who consumed fish more frequently were more likely to rate the fish more positively in both the blind and named sensory sessions (Figure 4.19). The positive effect of naming a fish on outcome ratings was stronger for those with frequent fish consumption compared to those with less frequent fish consumption habits. Therefore, the positive naming effect discussed earlier was likely driven by frequent seafood consumers who rated appeal and consumption intentions higher.

The addition of the interaction term in the model with fish consumption as a fixed effect did not substantively increase the expected predictive performance over a model that included consumption without an interaction term (LOO-CV model difference = 1.2, standard error = 2.3).

4.4.2.4 Post Experiment Survey

A total of 46 responses to the post-experiment survey were received (75% of the 61 panelists) with a median completion time of 5 minutes.

Haddock and Atlantic cod were tied for the top two fish most likely to be recommended by panelists to family and friends (72% would probably or definitely recommend). At least 50% or more of panelists would likely recommend Atlantic pollock and hake to family and friends. There was higher uncertainty (greater percent responding 'maybe' or 'not sure') for recommendations of fish types that panelists did not taste during the session (Table 4.10).

Since panelists experienced steamed fish during the sessions, the steamed preparation acted as an anchor, or reference point, for how each panelist preferred different seafood preparation styles. When asked to rank nine seafood preparation styles from most preferred to least preferred, panelist ranked grilled, baked, and fried as their top 3 most preferred fish preparation styles followed by sautéed, raw, steamed and smoked (tied), tinned, and then pickled.

Social influence was explored by asking panelists if they shared their experience tasting fish with friends and family. A total of 54% (n=33) of panelists responded "Yes" to talking about at least one fish that they liked. Among the 33 panelists, dogfish was talked about 29 times, Atlantic cod 28 times, haddock 26 times, and both Atlantic pollock and hake were talked about 24 times. Panelists widely noted that they shared their level of surprise and enjoyment in fish they have never tried before.

A total of 38% (n=23) of panelists responded "Yes" to talking about at least one fish that they did not like. Among the 23 panelists, dogfish was talked about 28 times, hake 17 times, haddock and Atlantic pollock 16 times, and Atlantic cod 15 times. Negative comments from panelists included how the stronger flavor and texture of dogfish was undesirable and how the other whitefish – cod, pollock, hake, and haddock- were bland.

A total of 52% (n=32) of panelists indicated their perception related to at least one species changed after participating in this experiment. Dogfish was most frequently mentioned. A total of 14 panelists said they shifted from a negative or neutral perception of dogfish to a positive perception. Conversely, two panelists shifted to a negative position on dogfish. A total of 10 panelists shifted to a positive perception of hake while eight panelists shifted to a positive perception of pollock. A total of two panelists shifted to a negative perception of Atlantic cod. Three panelists commented on how they would want to taste the fish with a different preparation method.

While methodology was designed to evaluate panelists responses to all species over the entire study, responses for Atlantic cod were not collected in the post-sensory survey due to error. However, given the positive ratings Atlantic cod received throughout the first three study components, it is expected that panelists would maintain positive perceptions of Atlantic cod throughout the entire study. Considering the above, haddock was the most positively rated species across the four study components and dogfish was the least positively rated species across the four study components.

4.5 Discussion

4.5.1 Insights for UMass Dining

Results showed that the UMass Millennial and Gen-Z community is highly unfamiliar with many of their local seafood options in both name and taste. Panelists were more familiar with New England's shellfish than finfish options. Notably, they were widely unfamiliar with all underutilized species except for haddock. Panelists showed some awareness of their disconnect to their local seafood options throughout the survey. Most panelists responded that their seafood purchasing decisions have not provided much business to New England fishermen, that they do not know a lot about their local seafood options or eat a large variety of wild-caught local seafood. Over 50% of panelists also felt that restaurants do not provide a large variety of local seafood options.

Certain results imply that panelists want to be more engaged with their local seafood options and seafood sustainability in general. Millennials and Gen-Zers may engage more with their local seafood options in the future if they receive information through social media, websites, or at point of sale, especially if the information was produced by trusted sources such as fisheries scientists, or state and federal government agencies. These results suggest that professionals who are rarely part of the seafood marketing realm, may be effective representatives for local sustainable seafood campaigns.

Answers from open-ended questions in the initial survey and post-sensory survey suggest that eating seafood was a memorable and shareable experience. Most panelists provided lengthy and rich descriptions of seafood dishes they recalled from childhood. As a result of the sensory sessions, most panelists also shared their experience tasting new fish with family and friends. More panelists shared a positive experience with family and friends than a negative experience.

These results suggest that the UMass community is hungry for more connections to local seafood and sustainability information. UMass Dining has the marketing resources, influence, and cooking expertise to make memorable and sharable experiences for the UMass community. In doing so, UMass Dining could use their purchasing power to support New England's fisheries and their food sustainability goals.

4.5.2 Marketing New England Seafood in a Changing Climate

While the initial online survey captured how Millennials and Gen-Z consumers want to receive seafood sustainability information, and who they trust for sustainability information, this study did not identify or test messages that could motivate seafood purchasing decisions. Nor did the study identify or test combinations of mediums, messengers, and messages. For instance, would a younger consumer be more prone to purchase Atlantic pollock if a fishermen, government fisheries scientist, or friend showed them it was locally caught, supported local jobs, was resilient or vulnerable to climate change, or was a widely enjoyed substitute for Atlantic cod? This is an important, unresolved question for future research.

UMass Amherst could test out several different marketing approaches to mobilize more support for local seafood. One approach could be centered around taking action to increasing awareness and mitigating the impacts of climate change. A campaign could focus on how a campus community can bolster support for New England fishermen as they combat economic impacts from extreme weather or more directly by specifying climate change. Our results show that over 60% of panelists perceived extreme weather as a serious threat to fishermen. Showing greater concern for how environmental issues affect others, rather than oneself, is not unheard of (Schultz 2001), and this heightened threat-awareness could promote actions within a climate-centered campaign. Messages that elicit feelings of pride, empowerment, and moral or ethical responsibility (Markowitz 2012; Markowitz and Shariff 2012) could mobilize campus communities and be effective (e.g. “Help keep New England fishermen afloat. Eat a diversity of local seafood”). Younger demographics with pro-environmental attitudes and an openness to new experiences, which this population provides, have been identitified in other research as populations more prone to being involved in pro-environmental actions (Markowitz et al. 2012). While openness to new experiences was asked through a narrow scope in the initial survey, the majority of panelists responded that they are open to a new culinary experience. Overall, UMass appears to have a promising population to test a novel climate-focused sustainable seafood campaign.

4.5.3 Insights for Restaurants

Results for the study provide several suggestions for how the broader community of New England restaurants can be more engaged with local seafood. Most notably, results indicate that haddock, Atlantic pollock, and hake are all highly rated by consumers and are desirable substitutes for Atlantic cod or other less sustainable whitefish options. Since 25% of Boston menus used cod on their menus (Chapter 3), replacing cod with one of these fish is one approachable way many Boston restaurants could increase their support for New England fishermen and offer more sustainable fish options without sacrificing consumer experience. In fact, consumers may be more likely to talk about their meal – and therefore the restaurant - with friends or family if they had a positive experience trying a lesser known species for the first time.

Aroma tended to be the least positively rated feature of all of the fish types, while taste and texture were the most positively rated features. In the initial survey, taste and aroma were the panelists’ first and fourth, respectively, most popular important attributes when deciding on a seafood purchase. Together, these results suggest that chefs can attract consumers to new fish species by emphasizing the taste and texture of a seafood dish and finding ways to enhance the aroma.

Results from the survey and sensory experiment could provide chefs with more specific information about consumer preferences and attitudes toward New England's local seafood, including all seven underutilized species. With this information, chefs may be inclined to adjust their menu options (helping increase familiarity and access) and preparations accordingly.

4.5.4 Reflection on Dogfish

Ratings for all fish species in the sensory experiment appeared unimodal except dogfish. Dogfish's bimodal distribution in ratings (Figure 4.12) could be attributed to having a more pronounced flavor than the other mild whitefish. Some panelists described the flavor and texture of dogfish as undesirable while other panelists commented that they enjoyed the bolder flavor and texture. The fact that dogfish fillets were thawed the morning of the sensory sessions could have contributed to some panelists experiencing an undesirable texture, and possibly flavor. Future research could identify if consumers react the same way to fresh dogfish as they do with frozen dogfish. Sensory assessments have suggested that panelists rate the flavor of prepared frozen seafood just as high as fresh seafood (Banse 2019); however, to the best of our knowledge, no sensory assessments including dogfish have been conducted to date. Almost all fresh dogfish is exported instead of kept within the United States (Wiersma and Carroll 2018).

Dogfish was the most frequently mentioned fish to family and friends in both a positive and negative manner. These split reactions to steamed dogfish - and proclivity to share both negative and positive experiences with dogfish - may confuse consumers, or create negative bias within consumers, who have not tried dogfish but hear mixed responses. If UMass dining or New England's seafood industry want to increase demand for dogfish, they may want to explore introducing dogfish to consumers through a preparation style that is more aligned to consumer interest (e.g. fried, grilled). These results suggest that UMass Dining should keep serving dogfish but offer different preparation styles to appeal to more students' preferences and reduce potential for creating negative bias through social influence.

4.5.5 Additional Future Research

The results of this study present several important questions to be addressed by future assessments of New England fish species.

Even though panelists ranked "steamed" as one of their least favorable preparation styles for fish in the post-sensory survey, steamed fish samples were rated fairly highly by panelists. This suggests that these underutilized species are well received by consumers even when cooked in a less desirable way. To better understand the real marketplace potential of these species, research is needed on how consumers react when fish is prepared in ways that align with consumers' favorite seafood preparation styles (e.g. fried, grilled) During the sensory sessions and post-sensory experiment there were several panelists who described how they would prefer a different cooking method for each fish type; often calling dogfish too fishy or the others too bland.

Along the same lines, it is important to evaluate if consumers can *distinguish* between fish with similar flavor profiles when they are prepared in an appealing way. Results of a triangle sensory experiment could encourage chefs to replace cod or other imported whitefish with locally harvested Atlantic pollock, haddock, or hake if ratings were equivalent or higher for underutilized species as alternatives.

Listing "whitefish", or not listing the fish at all, allows the chef to change the fish species used within dishes without explicitly informing the consumer. "Whitefish" was listed on 5% of Boston restaurant menus and unidentified fish was found on 25% of menus (Chapter 3). While listing "whitefish" on menus has been suggested as a strategy that chefs can use to support sustainable seafood (National Restaurant Association and US Foods 2019), there are potential caveats. Listing "whitefish", or not identifying fish type on menus, could potentially create mistrust from consumers who value transparency, or give the impression that the dish is inconsistent or cheap. Measuring and comparing consumer responses when cod, whitefish, and an underutilized species is listed on a menu is another research endeavor worth exploring for New England's seafood industry and restaurants.

4.5.6 Limitations

These findings are limited to our sample population at UMass Amherst of Gen-Z and Millennial individuals. While we captured information from groups (Millennials, Gen-Z, a university that makes large seafood purchases) that New England's seafood industry wants to target, our results do not fully represent other populations of interest (e.g., families making household purchasing decisions, etc.).

Our sample size was also a limiting factor. While we detected a small name effect from the blind to informed session, the study would have been more insightful if a separate suite of panelists repeated the study but participated in an informed session followed by the blind session. We do not know if the single direction of the sensory experiment design contributed to the name effect, in addition to other contributing factors. Additionally, a larger sample size would increase our statistical power while bringing forth more diverse written feedback about each species and the type of experience they chose to share with friends and family.

The narrow five- point response scale used for overall appeal and consumption intentions across this study was another limitation. This narrow scale may not have fully captured variation among participants or allowed variation in opinions and perceptions to be measured over all four assessment components. For instance, while model results suggested attitudes and intentions were not changed across the entire study, written responses in the post-sensory survey suggested that at least 32 of the panelists believed their attitudes and consumption intentions did change.

4.6 Conclusion

Overall, the combined results of this study: 1) provide insights about how Millennials and Gen-Zers relate to seafood and New England's seafood industry, and 2) provide elements that could help build a science-based marketing campaign for underutilized species with Millennials and Gen-Zers in New England as a target audience. Results reveal that these populations at UMass Amherst were highly unaware of the names and flavors of their local seafood options. Results also suggest that consumers found the taste and other sensory qualities of several lesser-known underutilized species to be on par with those of Atlantic cod. Panelists who frequently ate fish tended to rate fish species higher than panelists who ate fish less often. Finally, results show that panelists wanted to share both their positive and negative fish tasting experiences with friends and family. Together, these results could help create more memorable and sharable experiences as well as more targeted and engaging messages that could attract consumers to lesser-known New England species.

TABLES

Table 4.1: List of questions in the initial online survey

Familiarity	
	Have you HEARD OF these seafood items before? Have you TASTED the following seafood items before?
Past and Current Experience	
	In which state/country did you grow up? How often was seafood prepared in your household when you were growing up? What types of seafood dishes were prepared in your household when you were growing up? (Ex. "Clam chowder from a can" or "Tuna casserole" or "Tinned anchovies") Currently, how often do you consume seafood? Where do you eat seafood most often? Which seafood items are you eating most often? (Select up to 3)
Perceptions & Behavior	
	Overall, how would you rate the appeal of these fish? Would you order any of these fish at a UMass Dining facility (e.g. Bluewall, Baby Berk food truck, any of the dining commons)? Would you order any of these fish at a restaurant? In a restaurant, how likely are you to order a seafood item that you have never tried before?
Name Preference	Please *indicate which market name you prefer*
Purchasing & Sustainability	*Acadian Redfish or Ocean Perch?* Dogfish or Cape Shark? Porgy or Scup or Sea Bream?
	To what extent do you agree with this definition [for 'sustainable seafood']?
	How important are each of the following attributes when evaluating which seafood item to eat?

How often do you seek out sustainability information about a seafood item before making a purchasing decision?
To what extent are you interested in learning more about the sustainability of seafood items?
If you wanted to learn more about seafood sustainability, what would be the best way to receive information? *(Select up to three)*

Various *groups are offering sustainability information about seafood through websites, purchasing guides, eco-labels, social media, and seafood events.*
To what extent do you trust sustainability information about seafood from the following groups?

We *define sustainable seafood as seafood that is either caught or farmed in ways that consider the long-term vitality of harvested species, the well-being of the oceans, and the livelihoods of people who depend on fishing activities*

To what extent do you agree with this definition?

When *you purchase wild-caught local seafood, you are providing business to New England fishermen. Note: Purchasing Atlantic salmon does not provide business to New England fishermen because Atlantic salmon is farmed and primarily imported.*
Consider the types of seafood you purchase. How much business are you providing New England fishermen?
How much more business can you realistically provide to New England fishermen?

Currently, fish populations in New England are sustainably managed
In your opinion, how much does each group need to change in order for the seafood industry to reach peak sustainability?

All *of these groups want to create a more sustainable seafood industry in New England.*

	In your opinion, how much does each group need to change in order for the seafood industry to reach peak sustainability?
Self-Acknowledgments	To *what extent do you agree or disagree with the following statements:*
	I know a lot about my local seafood options
	I eat a large variety of wild-caught local seafood I have access to a large variety of local seafood in restaurants
Extreme Weather	Extreme *weather events include hurricanes, flooding, droughts, heatwaves, downpours, and winter storms (e.g. Nor'easters). To what extent do you agree with the following statements?*
	Extreme weather events occur in New England
	Extreme weather events are occurring more frequently in New England Extreme weather events are increasing in intensity How serious of a threat are extreme weather events… to wild fish population to New England fishermen to you and your family
Demographics & Qualifications	Do *you consider yourself a(n)…*
	consumer of seafood?
	recreational angler? environmentalist? activist? What is your gender? Were you born between January 1, 1980 - December 31, 2000? What year were you born in? What is the highest level of formal education that you have completed? What is your income? Do you have any food allergies or sensitivities?

Table 4.2: List of questions in the post sensory survey.

Perceptions & Behavior	
	Overall, how would you rate the appeal of these fish? Would you order any of these fish at a UMass Dining facility (e.g. Bluewall, Baby Berk food truck, any of the dining commons)? Would you order any of these fish at a restaurant? In a restaurant, how likely are you to order a seafood item that you have never tried before?
Cooking Preference	
	The samples you tasted during the experiment were steamed. Please drag and drop these different fish preparation methods to order from 1 (most preferred) to 9 (least preferred)
Social Influence	
	Would you recommend any of these fish to a friend or family member? Since the experiment, have you talked with any friends or family about a fish you tasted during the experiment that you DID like Which fish did you LIKE and talked about with friends and/or family? *(select all that apply)* What did you say about the selected fish and how did your friends/family respond? Since the experiment, have you talked with any friends or family about a fish you tasted during the experiment that you DID NOT like? Which fish did you NOT LIKE and talked about with friends and/or family? *(select all that apply)* What did you say about the selected fish and how did your friends/family respond?
Reflection	
	Would you like to tell us if your perceptions about any of these species has changed after participating in this experiment?

Table 4.3: Demographics of the panelists who completed the sensory experiment.

Question	Frequency	%		Frequency	%
Gender (n=61)			*Income*		
Female	33	54%	Less than $29,999	40	66%
Male	28	46%	$30,000-$49,999	14	23%
			$50,000-$69,999	1	2%
Generation			$70,000-$89,999	0	0%
Millennial	30	49%	Greater than $90,000	3	5%
Gen-Z	31	51%	Prefer not to answer	3	5%
Age					
18-22	31	51%			
23-27	17	28%			
28-32	7	11%			
33 and older	6	10%			
Education			*In which state/country did you grow up?*		
High School or GED	5	8%	Massachusetts	33	54%
Some College	25	41%	Connecticut	3	5%
Associate/Technical	2	3%	Rhode Island	1	2%
Bachelor's Degree	15	25%	New York	4	7%
Master's Degree	14	23%	Other within USA	6	10%
			*Other - Outside USA	9	15%
			Other - Did Not Respond	5	8%

Millennial is defined as anyone born between 1981-1996 and Gen-Z is defined as anyone born during or after 1997. Written responses for Other- Outside USA include Brazil, England, Republic of Congo, Philippines, Nigeria, India, Vietnam, and Thailand

Table 4.4: Panelists' past and current experience with seafood

Question	Frequency	%		Frequency
How often was seafood prepared in your household when you were growing up? (n=61)			*What Types of Seafood Do You Eat Most Often (select 3)*	
Two or more times per week	7	11%	Tuna	30
At least once per week	17	28%	Farmed Salmon	25
A few times per month	21	34%	Farmed Shrimp	21
Once per month	4	7%	Atlantic Cod	12
Once every 2-3 months	6	10%	Wild Salmon	12
Less than once every 3 months	5	8%	Clams	9
Other	1	2%	Haddock	9
			Tilapia	9
Currently, how often do you consume seafood? (n=61)			Wild Shrimp	9
Two or more times per week	6	10%	Mussels	6
At least once per week	24	39%	Scallops	6
A few times per month	23	38%	Lobster	4
Once per month	8	13%	Squid	4
Once every 2-3 months	0	0%	Black Sea Bass	3
Less than once every 3 months	0	0%	Halibut	3
Other	0	0%	Oyster	3
			Atlantic Pollock	1
Where do you most often consume seafood? (n=61)			Bluefish	1
Sit-in Restaurant	26	43%	Dogfish	1
Home Prepared	24	39%	Striped Bass	1
Fast food / Takeout	2	3%	Cusk	0
Other	9	15%	Hake	0
			Monkfish	0
			Scup	0
			Skate	0
			Swordfish	0
			Tautog	0

Table 4.5: Words most frequently used when describing seafood dishes from childhood. Responses from panelists and non-panelists when asked "What types of seafood dishes were prepared in your household when you were growing up?"

	Nonpanelist (n=84)		Panelist (n=49)	
Word Used	**Frequ**	**%**	**Frequ**	**%**
fish	71	85%	39	80%
salmon	59	70%	28	57%
tuna	52	62%	31	63%
shrimp	49	58%	38	78%
baked	38	45%	18	37%
fried	32	38%	13	27%
grilled	31	37%	14	29%
clam	25	30%	13	27%
chowder	23	27%	13	27%
lobster	22	26%	9	18%
steamed	21	25%	8	16%
cod	21	25%	18	37%
scallops	17	20%	11	22%
clams	15	18%	10	20%
haddock	14	17%	9	18%
canned	14	17%	12	24%

Text mining showed which words were most frequently used and how results did not significantly differ between panelists and non-panelists. A total of 49 of the 61 panelists (80%) and 84 of the 103 non-panelists (82%) responded to this question.

Table 4.6: Posterior Summaries of the Name Effect model.

	Posterior Median	*95% Lower HPDI*	*95% Upper HPDI*
Fixed Effects:			
Intercept	5.89	5.070	6.680
Wave (*Reference = Blind*)	0.226	-0.028	0.458
Varying Slopes for Wave:			
Item	0.119	< 0.001	0.376
Fish	0.092	< 0.001	0.323
Varying Intercepts for Ratings:			
Panelist	0.849	0.704	1.030
Item	0.412	0.152	0.912
Fish	0.689	0.308	1.35

Median= median of posterior distribution, HPDI = highest posterior density intervals. Varying slope and intercept estimates reflect standard deviations.

Table 4.7: Posterior Summaries of the Wave Effect model

	Posterior Median	*95% Lower HPDI*	*95% Upper HPDI*
Fixed Effects:			
Intercept	3.42	2.50	4.28
Wave 2 (*Reference = Wave 1*)	-0.402	-1.00	0.183
Wave 3 (*Reference = Wave 1*)	-0.073	-0.744	0.556
Wave 4 (*Reference = Wave 1*)	0.115	-0.351	0.605
Varying Slopes for Wave:			
Item – Wave 2	0.373	0.132	0.836
Item – Wave 3	0.340	0.097	0.803
Item – Wave 4	0.241	0.002	0.666
Fish – Wave 2	0.174	0.001	0.482
Fish – Wave 3	0.352	0.119	0.747
Fish – Wave 4	0.197	< .001	0.501
Varying Intercepts for Ratings:			
Participant	0.560	0.456	0.668
Item	0.478	0.147	1.290
Fish	0.477	0.166	1.090

Median=median of the posterior distribution, HPDI= highest posterior density intervals. Varying slope and intercept estimates reflect standard deviation.

Table 4.8: Posterior summaries of the Name Effect Interaction model.

	Posterior Median	*95% Lower HPDI*	*95% Upper HPDI*
Fixed Effects:			
Intercept	5.91	5.16	6.73
Wave (*Reference = Blind*)	0.214	-0.030	0.457
Consumption Frequency (z-scored)	0.140	-0.096	0.370
Interaction Term	0.118	0.006	0.230
Varying Slopes for Wave:			
Item	0.122	< 0.001	0.380
Fish	0.084	< 0.001	0.298
		.	
Varying Intercepts for Ratings:			
Panelist	0.818	0.670	1.00
Item	0.422	0.162	0.934
Fish	0.635	0.279	1.250

Median = median of posterior distribution, HPDI = highest posterior density intervals. Varying slope and intercept estimates reflect standard deviations.

Table 4.9: Posterior Summaries of the Wave Effect Interaction model

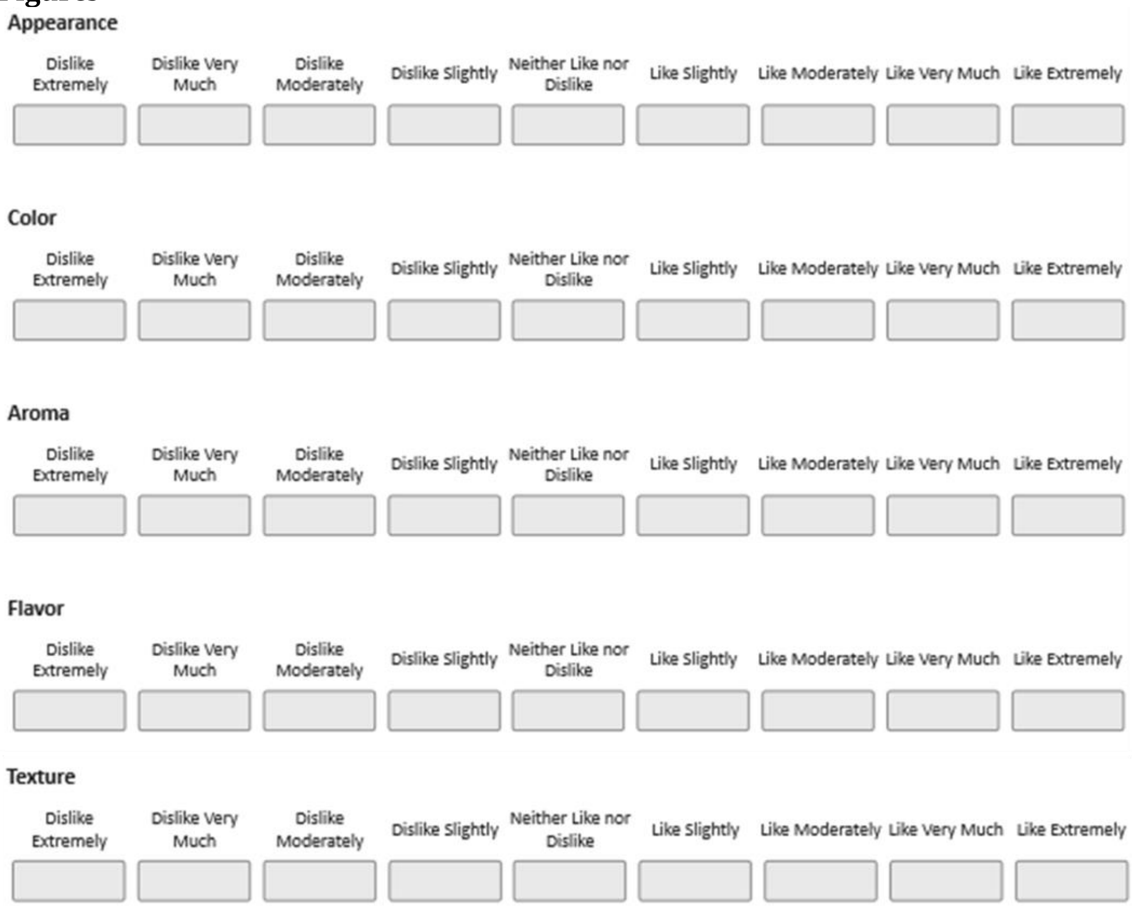
	Posterior Median	*95% Lower HPDI*	*95% Upper HPDI*
Fixed Effects:			
Intercept	3.370	2.420	4.300
Wave 2 (*Reference = Wave 1*)	-0.383	-0.994	0.228
Wave 3 (*Reference = Wave 1*)	-0.009	-0.682	0.645
Wave 4 (*Reference = Wave 1*)	0.111	-0.438	0.652
Consumption Frequency (z-scored)	0.184	0.014	0.344
Interaction Term 1 (*Wave 2 term*)	-0.078	-0.178	0.019
Interaction Term 2 (*Wave 3 term*)	0.016	-0.077	0.118
Interaction Term 3 (*Wave 4 term*)	-0.015	-0.102	0.085
Varying Slopes for Wave:			
Item – Wave 2	0.373	0.124	0.827
Item – Wave 3	0.345	0.111	0.789
Item – Wave 4	0.212	< 0.001	0.634
Fish – Wave 2	0.222	0.031	0.573
Fish – Wave 3	0.377	0.145	0.768
Fish – Wave 4	0.294	0.097	0.664
Varying Intercepts for Ratings:			
Panelist	0.553	0.450	0.661
Item	0.486	0.137	1.260
Fish	0.474	0.195	1.100

Median = median of posterior distribution, HPDI = highest posterior density intervals. Varying slope and intercept estimates reflect standard deviations.

Table 4.10: Likelihood of recommend select seafood species. The percent of panelists that would likely and not likely recommend each fish type to family or friends. Fish types are ranked based on the percent panelist would "probably" or "definitely" recommend to family or friends

Fish Type	Definitely Not or Probably Not	Maybe	Probably or Definitely	Not Sure
Haddock	13%	9%	72%	7%
Atlantic Cod	13%	11%	72%	4%
Black Sea Bass	11%	15%	59%	15%
Atlantic Pollock	17%	15%	57%	11%
Hake	13%	26%	50%	11%
Dogfish	35%	13%	43%	9%
Redfish	15%	20%	35%	30%
Summer Flounder	20%	26%	35%	20%
Butterfish	15%	26%	30%	28%
Scup	28%	28%	24%	20%

Figures



Appearance

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Color

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Aroma

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Flavor

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

Texture

Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely

*Figure 4.1A (top) and 4.1B (bottom)**:** The Compusense interface during the sensory experiment. Panelists used this interface when they rated overall appearance, color, aroma, flavor, and texture of steamed fish samples during the blind session (top). The Compusense interface panelists used when they rated overall appeal, consumption interest, and provided comments of steamed fish samples during the blind session (bottom). These interfaces appeared after panelists provided their consent and reviewed instructions.*

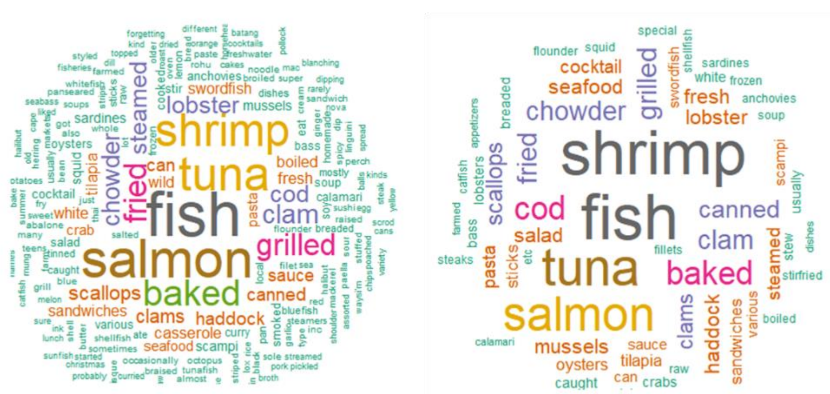


Figure 4.2A (left) and Figure 4.2B (right): Wordclouds of seafood dishes from childhood. These wordcloud were created from open responses when non-panelist (left) and panelists (right) were asked "What types of seafood dishes were prepared in your household when you were growing up?"

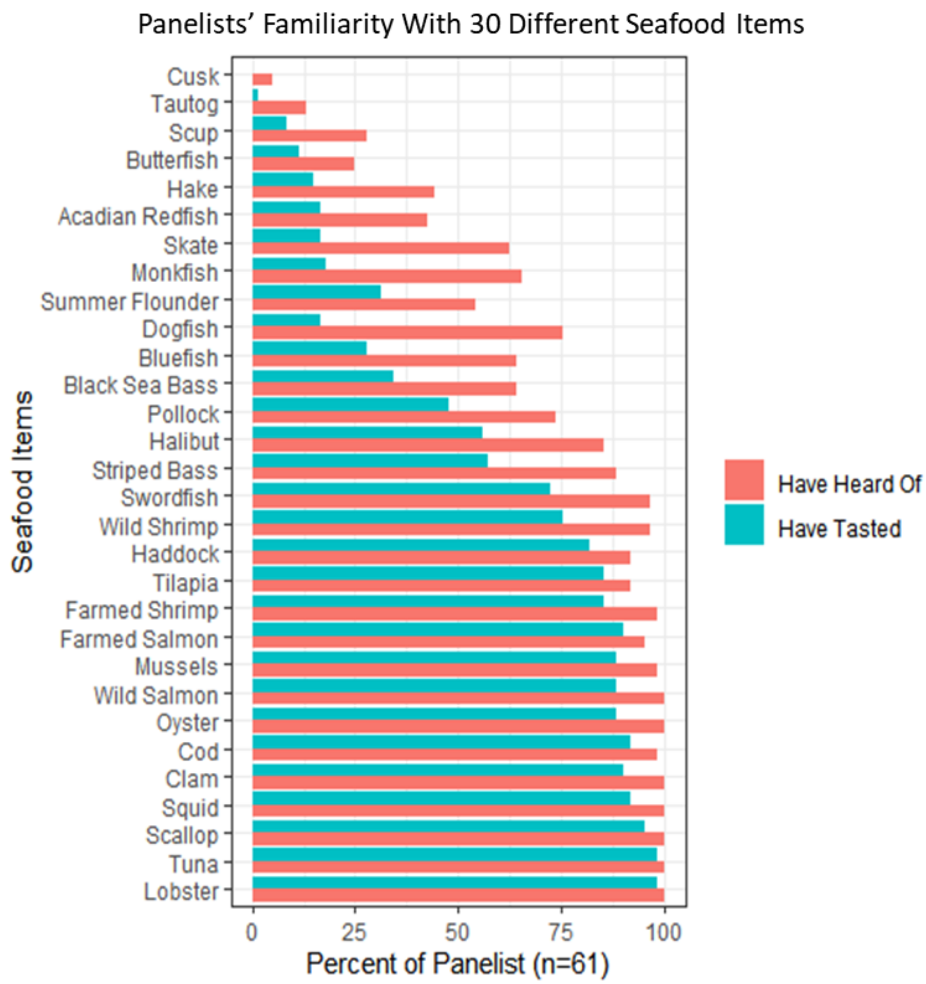


Figure 4.3: Panelists' familiarity with select seafood items. The percent of panelists that said "Yes" when asked "Have you heard of the following seafood items?"(in red) and "Have you tasted the following seafood items?"(in blue). Responses not shown include "No" and "Not Sure".

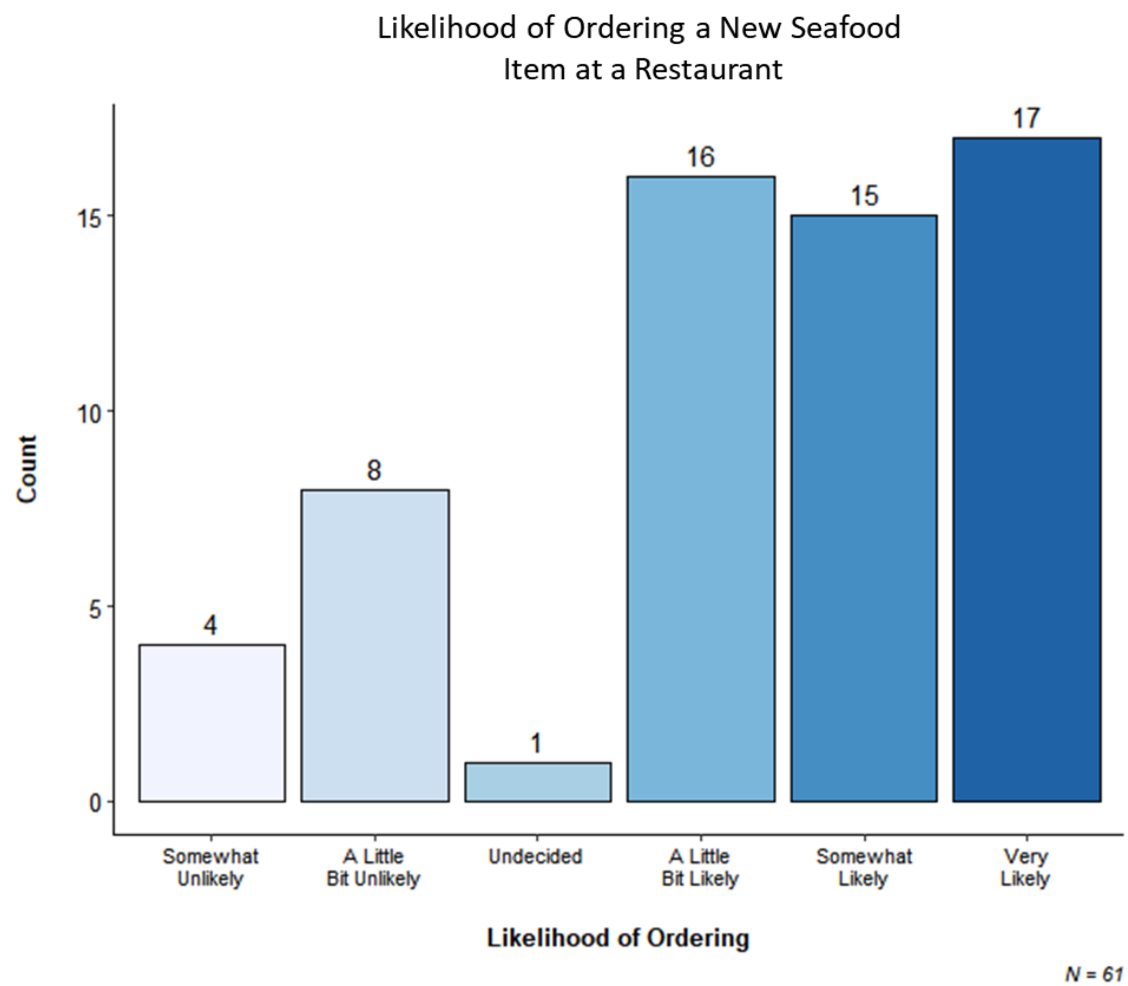


Figure 4.4: Likelihood of ordering an unfamiliar seafood item. Panelists' responses to how likely they are to order a seafood item they have never tried before in a restaurant..

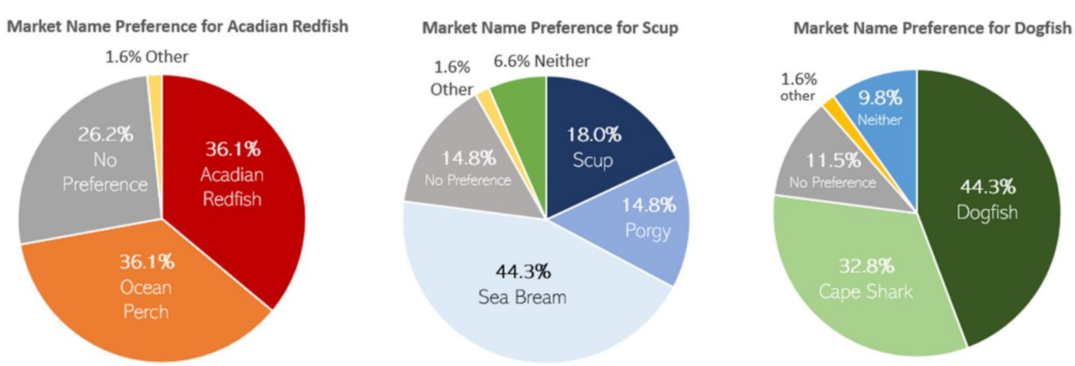


Figure 4.5: Marketname preference for select seafood items. Results when panelists were asked to indicate which market name they prefer for the following fish: Acadian redfish/ocean perch, scup/porgy/sea bream, and cape shark/dogfish. Neither, other, and no preference were also available for panelists to select.

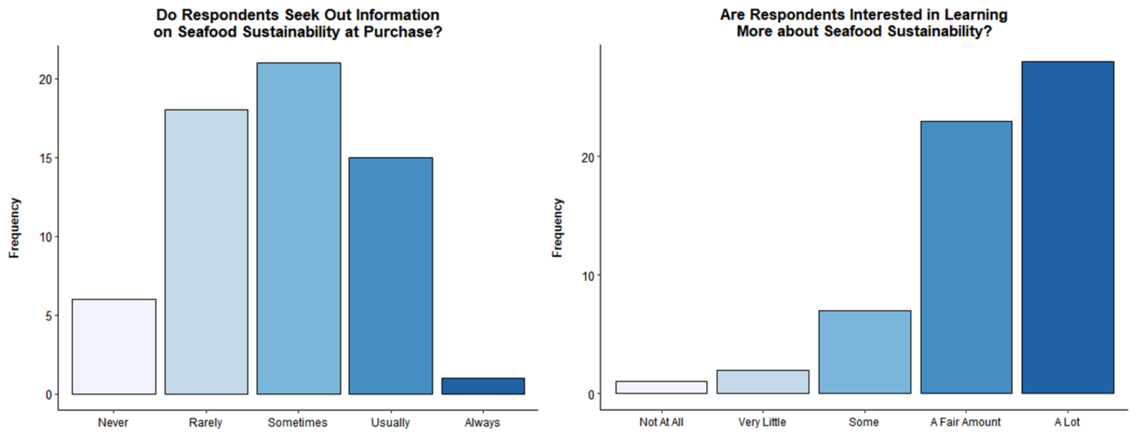


Figure 4.6A (left) and Figure 4.6B (right): Panelists' interest in sustainability. The number of panelists who say they never, rarely, sometimes, usually or always seek out sustainability information about a seafood item before making a purchasing decision (left). The number of panelists who say they are not at all, very little, some, a fair amount, and a lot interested in learning more about the sustainability of seafood items

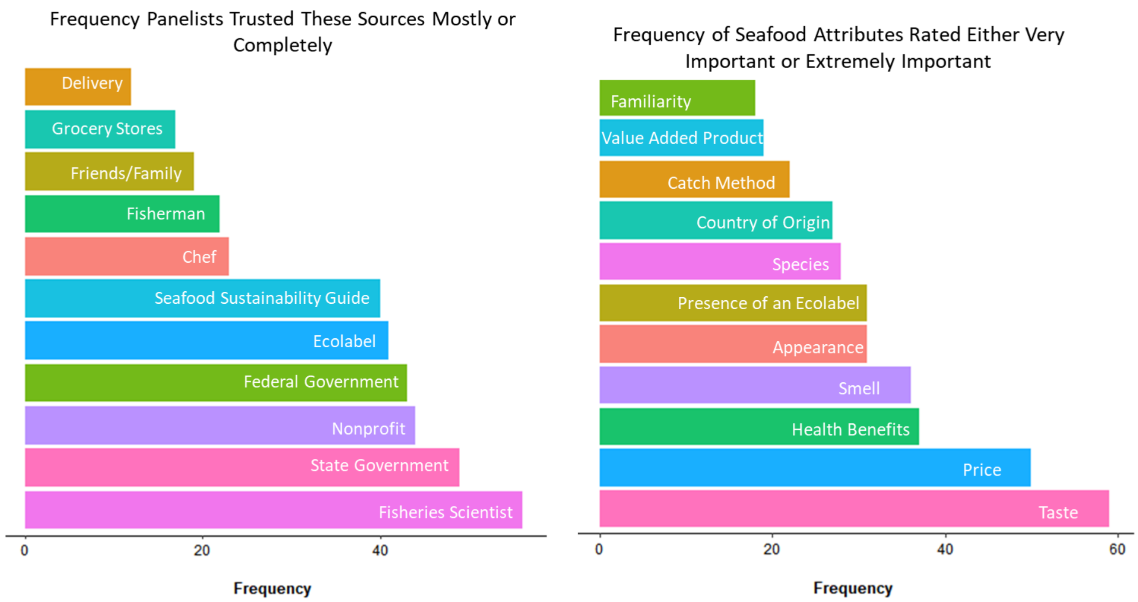


Figure 4.7A (left) and Figure 4.7B (right): Results about trust and important attributes. The frequency panelists rated groups that they would trust mostly or completely for seafood sustainability information (left). The frequency panelists rated attributes as either very important or extremely important when they evaluate which seafood item to eat (right).

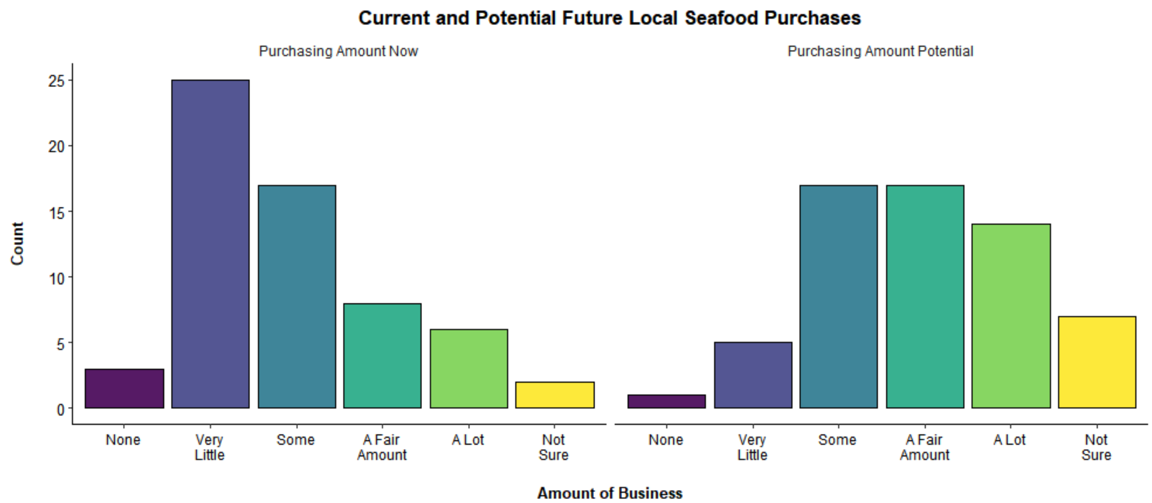


Figure 4.8A (left) and Figure 4.8B (right): The number panelists who felt their seafood purchases provided no to some degree of business to New England fishermen (left). The number of panelists who felt their future seafood purchases could provide no to some degree of business to New England fishermen (right).

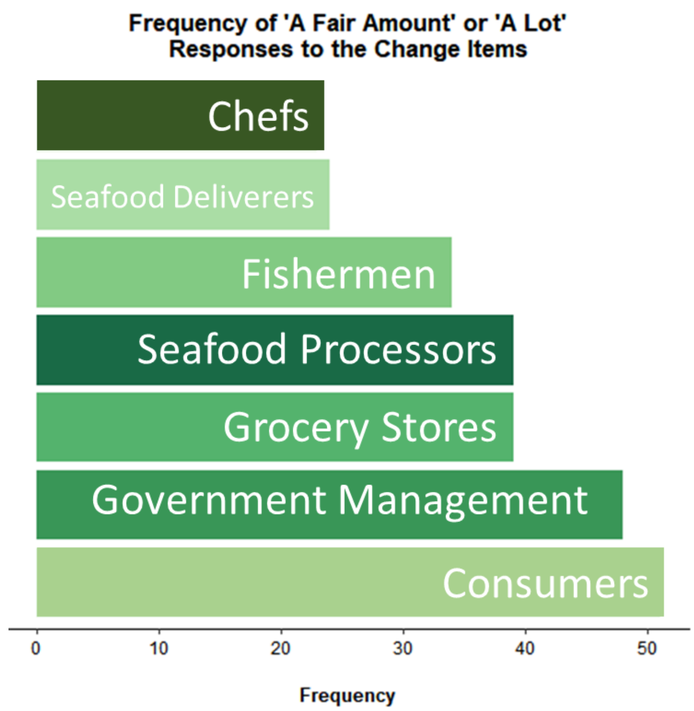


Figure 4.9:Panelists' expectations of change in seafood industry groups. The number of panelists who felt each group needed to change 'a fair amount' or 'a lot' in order for the seafood industry to reach peak sustainability.

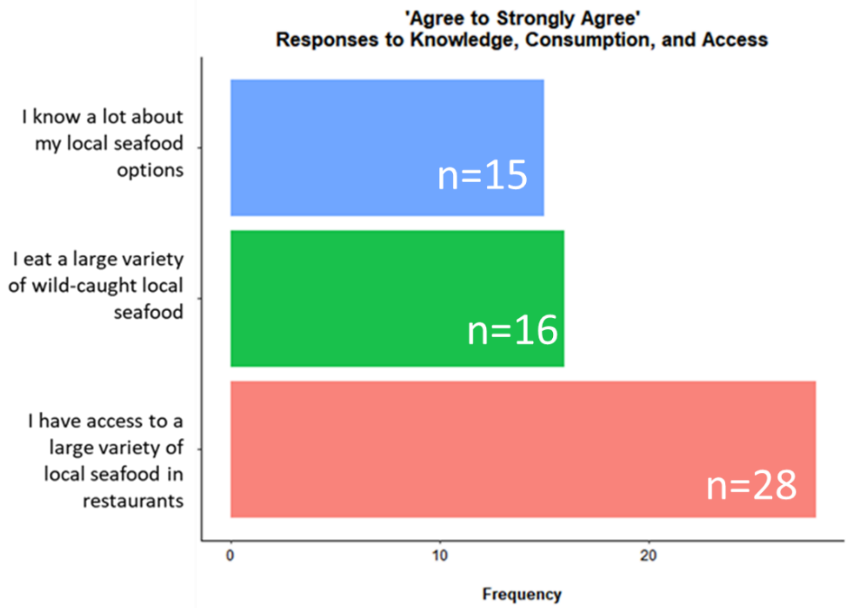


Figure 4.10: Agreement with knowledge, consumption, and access statements. The number of panelists (N=61) who somewhat agreed to strongly agreed to each statement.

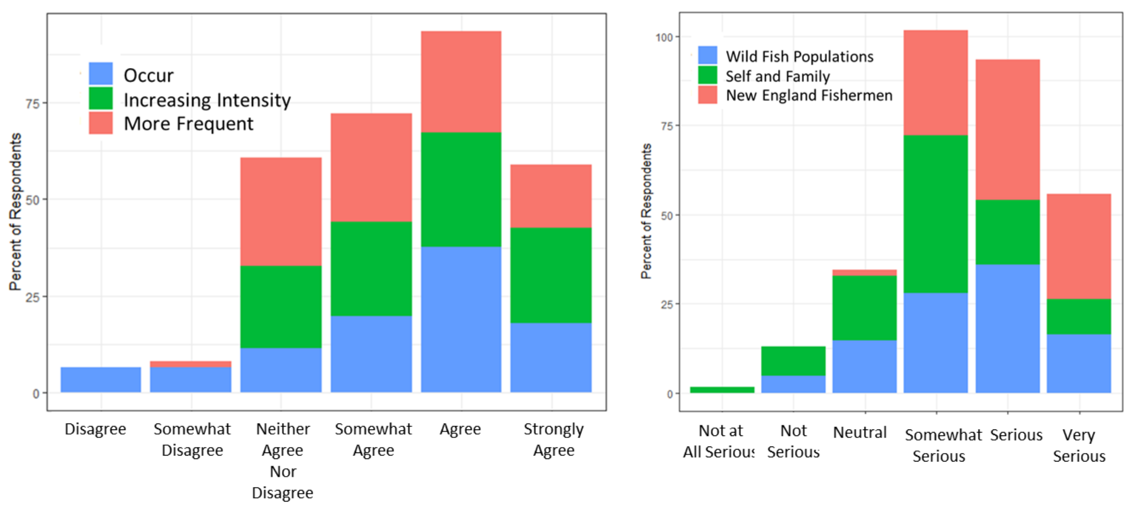


Figure 4.11A(left) and Figure 4.11B (right): Views about extreme weather events. The percent of panelists who disagreed to strongly agreed to statements about the occurance, frequency, and increasing intensity of extreme weather events in New England (left). The percent of panelist who rated the impact extreme weather events have on themselves and their family, New England fishermen, and wild fish populations.

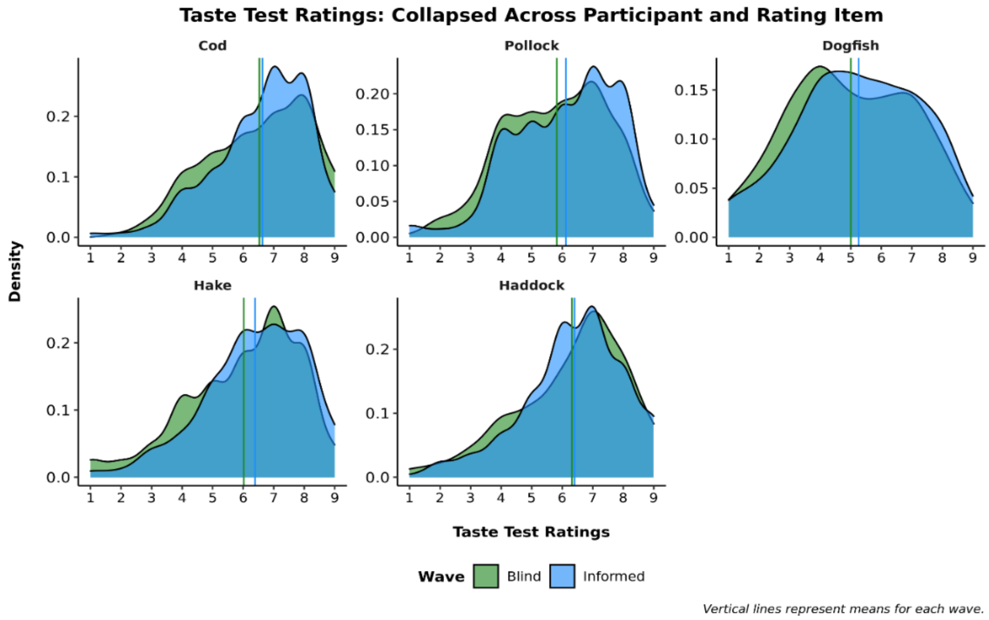


Figure 4.12: Taste ratings from both sensory sessions. Ratings are collapsed across panelist and rating item. Ratings come from 61 panelists in a within-subjects design.

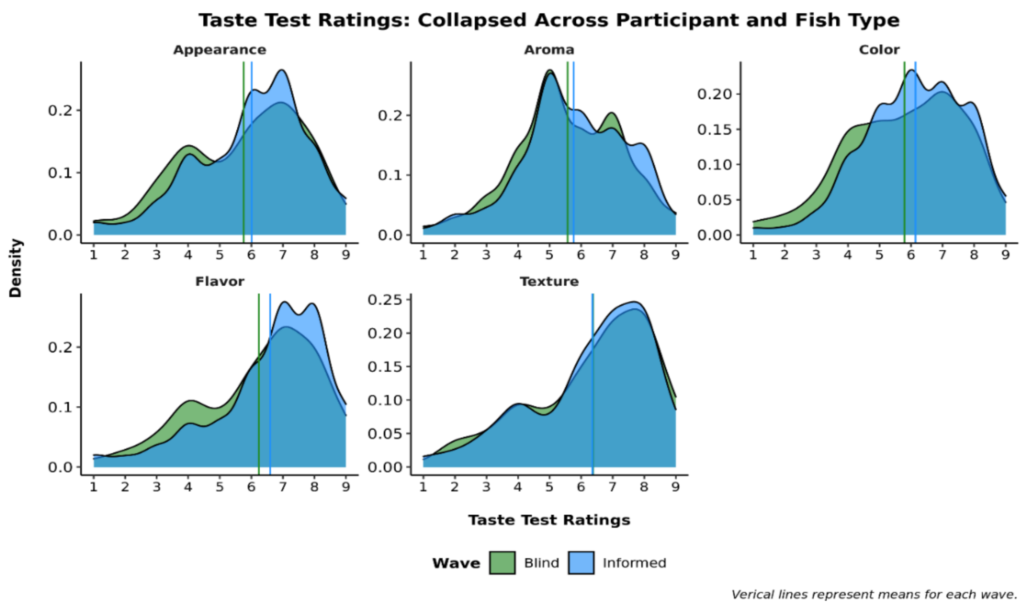


Figure 4.13: Attribute ratings in both sensory sessions. Taste test ratings collapsed across panelist and fish type. Ratings come from 61 panelists in a within-subjects design.

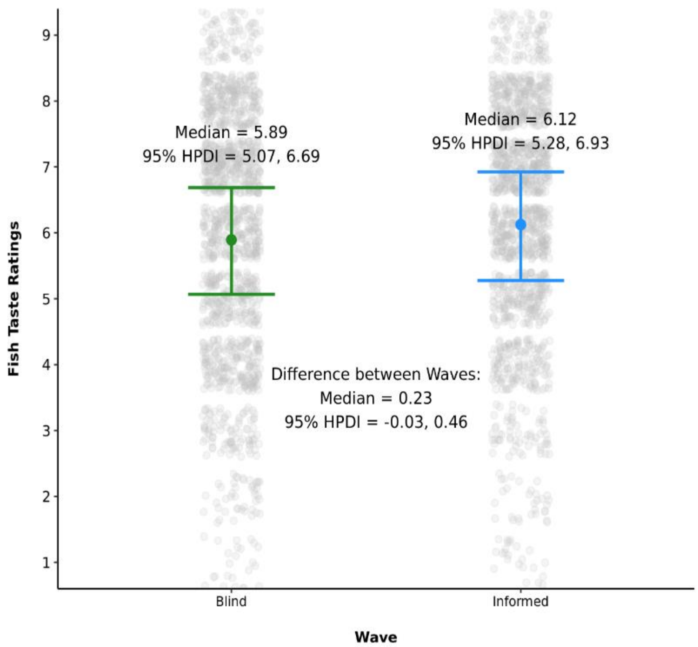


Figure 4.14: Results of the Name Effect model. The grey points are jittered representations of the raw data, while the point estimate and error bars denote the posterior medians and 95% highest posterior density intervals

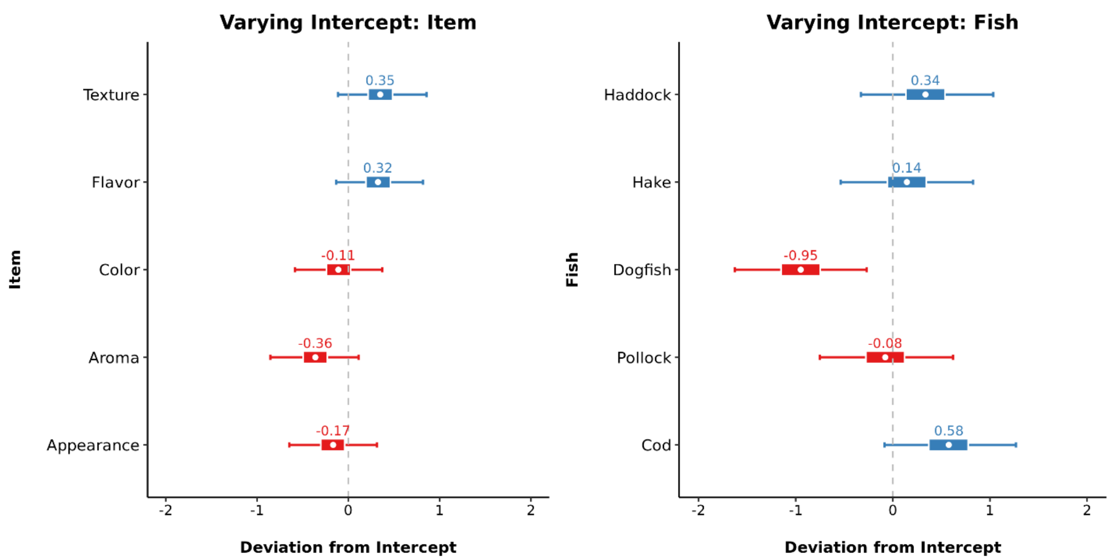


Figure 4.15A (left) and 4.15B: Varying intercept estimates for attributes and fish type from the name effect model. Positive values (blue) indicate the estimates for that term were higher than the overall intercept. Negative values (red) indicate the estimates for that term were lower than the overall intercept. Clear circles and values printed above each box are posterior medians. Colored boxes are 50% highest posterior density intervals, and extended lines are 95% highest posterior density intervals.

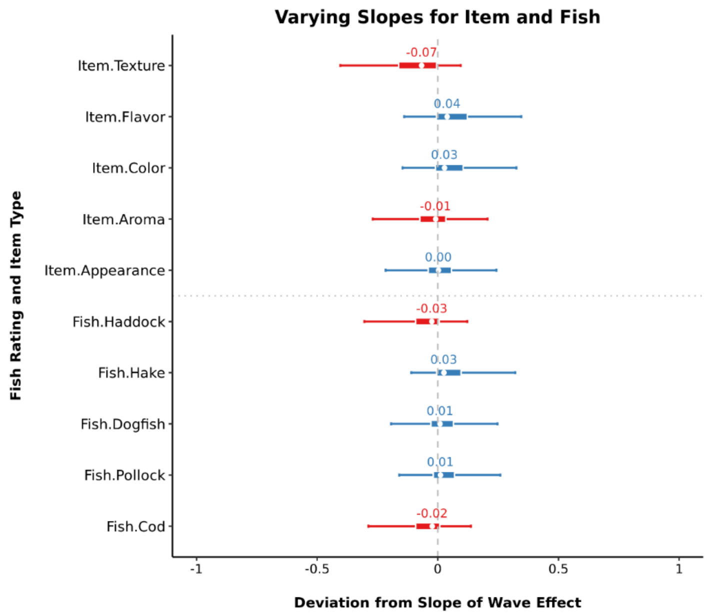


Figure 4.16: Varying slope estimates derived from the name effect model. The top half of the plot provides the slopes for each item, while the bottom half provides the slopes for each fish type, separated visually by the horizontal dotted line. Positive values (blue) indicate the estimates for that term were higher than the average slope. Negative values (red) indicate the estimates for that term were lower than the average slope. Clear circles and values printed above each box are posterior medians, colored boxes are 50% highest posterior density intervals, and extended lines are 95% highest posterior density intervals.

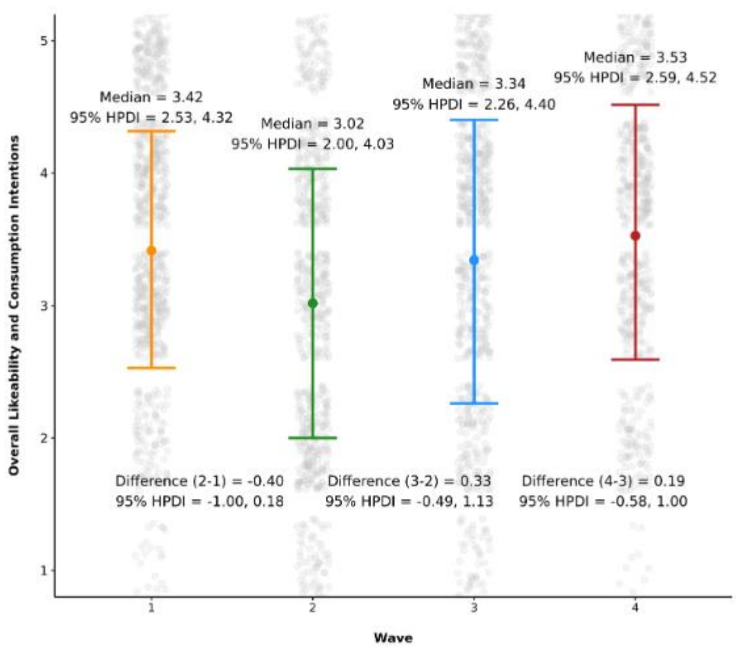


Figure 4.17: Variation across each study component derived from the wave effect model. Grey points are jittered representations of the raw data. Point estimates and error bards denote the posterior medians and 95% highest posterior density intervals. Wave 1= baseline (initial online survey), Wave 2= blind sensory session, Wave 3= informed sensory session, and Wave 4 =post-sensory survey.

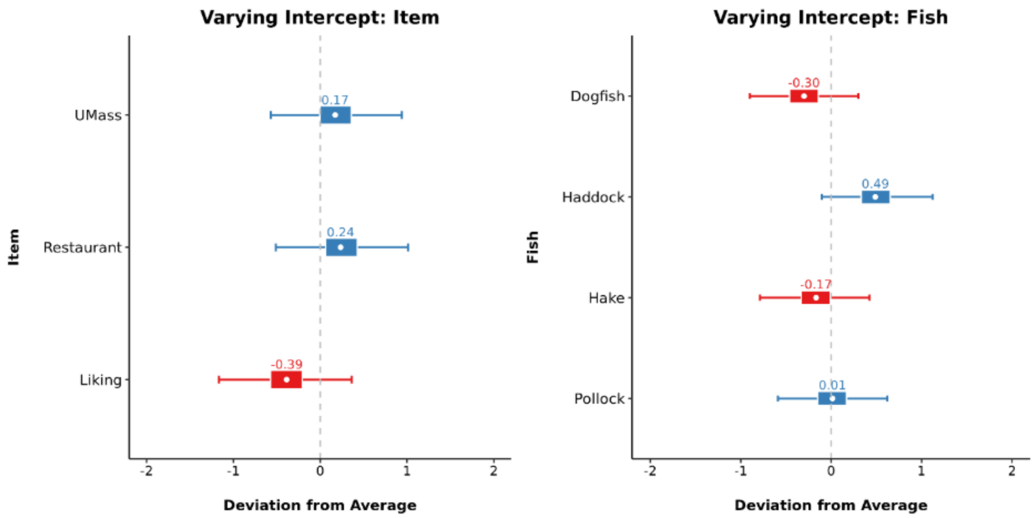


Figure 4.18A (left) and Figure 4.18B (right): Varying intercepts estimates for attributes and fish types from the wave effect model. Positive values (blue) indicate the estimates for that term were higher than the overall intercept. Negative values (red) indicate the estimates for that term were lower than the overall intercept. Clear circles and values printed above each box are posterior medians. Colored boxes are 50% highest posterior density intervals and extended lines are 95% highest posterior density intervals.

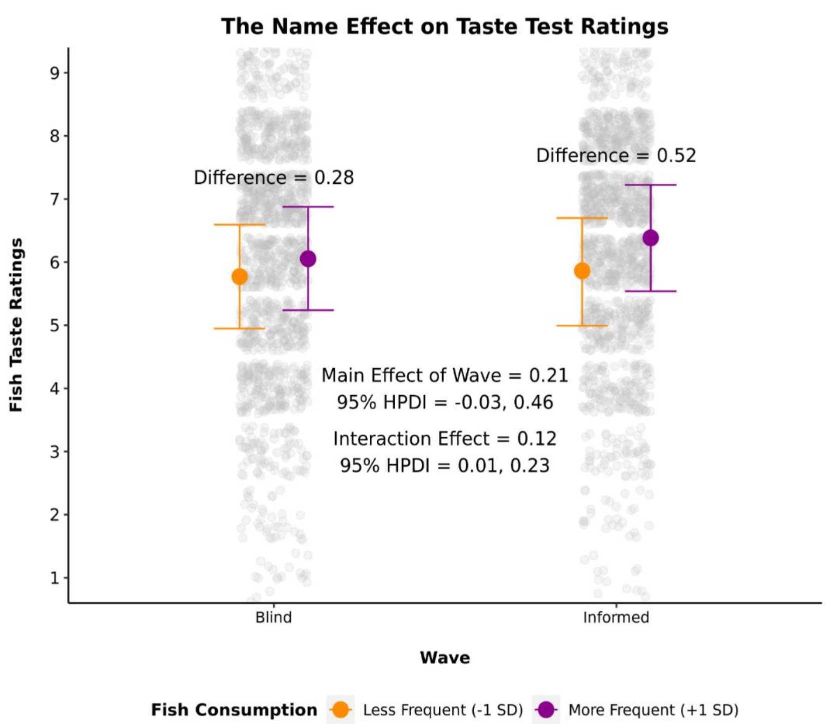


Figure 4.19: Results of the Name Effect Interaction model. The grey points are jittered representations of the raw data. Point estimate and error bars denote the posterior medians and 95% highest posterior density intervals. Fish consumption was z-scored for analysis. Plus or minus 1 standard deviation from the mean of the scale is denoted with "-1 SD" and "+1 SD". The annotations for differences reflect the difference in posterior median estimates between more and less frequent fish consumers.

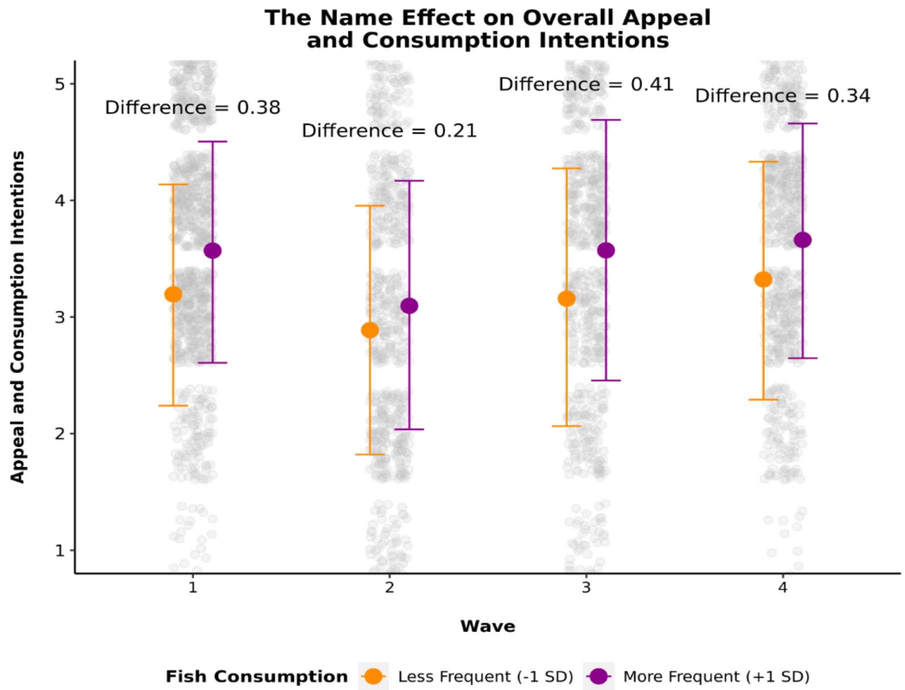


Figure 4.20: Results of the Name Effect Interaction model and ratings across the study components. The grey points are jittered representations of the raw data. The point estimates and error bars denote the posterior medians and 95% highest posterior density intervals. Wave 1= baseline (initial online survey), Wave 2= blind sensory session, Wave 3= informed sensory session, and Wave 4 =post-sensory survey. Fish consumption was z-scored for analysis. Plus or minus 1 standard deviation from the mean of the scale is denoted with "-1 SD" and "+1 SD". The annotations for differences reflect the difference in posterior median estimates between more and less frequent fish consumers.

CHAPTER 5

FUTURE CONSIDERATIONS

Results from these combined research endeavors suggest that underutilized species have substantial marketplace potential. Incorporating more of these species more often into the marketplace would likely provide relief to New England's seafood industry as climate change challenges their professional livelihoods and help them reach their sustainability goals. Moving forward, it is important to recognize and communicate how our seafood purchases, social influence, and carbon footprints will shape the future of New England's fishing industry.

In this thesis, I showed that in 2018 there were seven fish species among eight fish stocks that were abundant in New England's waters and could withstand additional fishing activity, but only one species (haddock) has been widely available to consumers in the marketplace.

The absence of the other six species (Acadian redfish, Atlantic pollock, white hake, silver hake, butterfish, and scup) in the marketplace may have social, cultural, and economic consequences. The level of presence in markets and restaurants explains why many younger persons have heard of and tasted haddock (high presence) but are so unfamiliar with the other six underutilized species. The widespread absence of these six species may be disconnecting consumers from their local seafood options. In addition to being unfamiliar with many of their local species, consumers may also have a false concept of New England seafood since the marketplace is filled with the same three types highly imported seafood (farmed shrimp, farmed salmon, and tuna) rather than a diversity of locally caught species. Furthermore, when/if the consumer is presented with the opportunity to purchase an underutilized species that is unfamiliar to them, they could have the impression that the reason the species is not more widely available to them is because it is less suitable for cooking or is less enjoyable than more popular options. These social, cultural, and economic consequences can be undone by reconnecting consumers to their underutilized species.

Results in Chapter 4 demonstrate that white hake and Atlantic pollock are rated favorably by consumers despite being unfamiliar to consumers. While this research did not evaluate consumer response to the other underutilized species, they too have received positive feedback from other research endeavors by Eating with the Ecosystem and the Commercial Fisheries Research Foundation. It is important to connect consumers to these lesser-known and underutilized species in the future if New England's seafood industry, and consumers, want a more sustainable and vibrant relationship with their local seafood.

Participants in our sensory assessments demonstrated that they wanted to be more connected with these underutilized species. These Millennials and Gen-Zers showed an eagerness to share their new seafood experiences, especially positive experiences, with their social circle. Positive responses to these species suggest that these species could successfully compete in the marketplace. Therefore, there should be more purchasing opportunities for consumers in the future whether it be in restaurants or in food markets. Currently, consumers have ample opportunities to purchase imported fish and few opportunities to purchase most of the underutilized species.

But we know markets and restaurants in New England can change their seafood options – we have seen it happen throughout history with lobster, tuna, and squid. Carving out more space for underutilized species on menus and within markets is possible provided there is collaboration throughout the supply chain and effective new marketing initiatives. It is important to direct some marketing initiative towards Millennials and Gen-Zers since their decisions will greatly sculpt the short-term and long-term viability of these underutilized species and New England's fisheries, especially as they create families and they choose which types of seafood their children will both eat and remember. New England's seafood supply chain could increase their connection with these younger generations by building rapport and trust with them and their communities on social media, explaining why they should purchase underutilized species, directing them on where they can purchase underutilized species, and showcasing attractive ways to prepare the fish at home that reflect the diversity of cultures within the Millennial and Gen-Z population. The supply chain may also want to consider collaborating on a new or existing New England-specific label or tools that clearly communicate sustainability information and celebrate the species being harvested by New England fishers. Another way New England's supply chain could direct consumers' seafood choices and increase trust is by releasing an annual list of species that are underutilized - ultimately increasing seafood transparency by pulling consumers into the ongoing sciences and decisions within fisheries management.

Our future actions can help mitigate climate change impacts on New England's fisheries. Reducing our carbon footprints and greenhouse gas emissions can simultaneously help create a more stable and predictable future for our fishing communities and fish populations. Modifying food choices is one immediate way both individuals and food service businesses in New England can reduce their carbon footprints. Substituting animal proteins with high carbon footprints (e.g. red meat and imported seafood) with a diversity of locally-caught fish and shellfish would simultaneously reduce the carbon footprint of eating behavior while fostering support for the seafood industry in a changing climate. Mitigating climate change impacts will also provide relief to fisheries management. Currently, management policies - especially policies pertaining to Atlantic cod - may already make the underutilized species within the Northeast Multispecies Fisheries Management Plan economically unattractive and risky to target. Further shifts in location, population size, predator-prey dynamics, etc. driven by climate change could make policy adjustments more difficult to draft and implement in a timely manner for underutilized species.

If we do not change our carbon footprints and greenhouse gas emissions, then there appears to be different windows of opportunity to market each of these underutilized species since each species has exhibited a different response to warming ocean temperatures and have different vulnerabilities to future warming conditions. Results from Chapter 2 suggest that the supply chain has the shortest window of opportunity to market Acadian redfish. They are sensitive to warming temperatures and are projected to have the largest northward shift relative to the other six underutilized species (over 800km) under RCP 8.5 (Morley et al. 2018) and lose almost half of their historic suitable thermal habitat area (Kleisner et al. 2017) by the end of the century. Meanwhile, there appears to be ample time to create markets for scup and butterfish since they can thrive in a wider range of temperatures and may be increasingly moving into the Gulf of Maine from the Mid-Atlantic region.

While scup and butterfish are likely to benefit from warming climate conditions, they were largely left out of climate studies so their biological and ecological responses in a warming scenario are not fully understood. We see that additional climate research and monitoring is needed on all underutilized species in the future since they are all important prey species and there is high uncertainty on how species interactions will change with shifts in phenology and fishing pressure (Weiskopf et al. 2020). Each species response, and the cascading ecological and economic responses, should be considered as these species are marketed in a changing climate.

Final Remarks

Ideally, this research will help New England's fishing industry move forward towards their sustainability and resiliency goals during a changing climate. There is promise in identifying underutilized species annually and sharing this information with consumers and the supply chain, aligning marketing efforts that will target Millennials and Gen-Zers, and reconnecting New England consumers to their fisheries. Overall, I hope this research will encourage all involved in New England's seafood industry – from boat to plate - to take the actions that will make these underutilized species - and all underutilized species in the future - attractive to target, sell, and eat.

SUPPORTING INFORMATION – SOURCES OF FISHERIES DATA

Species	Cumulative Catch & Annual Catch Limit	URL
Acadian Redfish	NOAA Fisheries Northeast Monitoring Reports	https://www.greateratlantic.fisheries.noaa.gov/ro/fso/reports/h/nemultispecies.html
Atlantic Pollock	NOAA Fisheries Northeast Monitoring Reports	https://www.greateratlantic.fisheries.noaa.gov/ro/fso/reports/h/nemultispecies.html
Haddock	NOAA Fisheries Northeast Monitoring Reports	https://www.greateratlantic.fisheries.noaa.gov/ro/fso/reports/h/nemultispecies.html
White Hake	NOAA Fisheries Northeast Monitoring Reports	https://www.greateratlantic.fisheries.noaa.gov/ro/fso/reports/h/nemultispecies.html
Species	**Cumulative Catch & Quota**	**URL**
Butterfish	NOAA Fisheries Quota Report Archives	https://www.greateratlantic.fisheries.noaa.gov/ro/fso/reports/quotareportarchives_home.html
Scup	NOAA Fisheries Quota Report Archives	https://www.greateratlantic.fisheries.noaa.gov/ro/fso/reports/quotareportarchives_home.html
Species	**Annual Catch Limit**	**URL**
Silver Hake	Small-Mesh Multispecies Specifications - May 2015	https://s3.amazonaws.com/nefmc.org/15mulsmallneshspecsfr.pdf
	Northeast Multispecies Fishery Management Plan; Amendment 19	https://s3.amazonaws.com/nefmc.org/amend19final_rule.pdf
	Cumulative Catch	**URL**
	Small-Mesh Multispecies Fishing Year 2018-2020 Specifications Review	https://s3.amazonaws.com/nefmc.org/2018-2020-Specifications-Document-final.pdf
	Annual Monitoring Report for Fishing 2017 - Small-Mesh Multispecies	https://s3.amazonaws.com/nefmc.org/5_Annual-Monitoring-Report-for-Fishing-Year-2017_180919_150658.pdf

APPENDIX

PROFILES OF UNDERUTILIZED SPECIES

Acadian Redfish (Sebastes fasciatus)

Overview

The Acadian redfish (*Sebastes fasciatus*) is one of three rockfish species in the Sebastes genus found within the Gulf of Maine. Acadian redfish prefer cool deep waters from Newfoundland's Grand Banks to the Gulf of Maine. These fish are well known for ovoviviparous reproduction, low fecundity, slow growth, and their long-life span (Sandeman 1969; Pikanowski et al. 1999)**.**

The most recent estimates suggest a median age at maturity of 5.5 - 6.6 years (Mayo et al. 1990; Sullivan et al 2017). Estimates of median length at maturation for females and males are similar - between 20.3 cm and 22.6 cm for females and 20.2 cm to 21.3 cm for males (Mayo et al 2002).Mating occurs in late fall and early winter when most males are mature (O'Brien et al 1993). Larvae emerge from late spring to August after a 45-60 day incubation period (O'Brien et al. 1993). Acadian redfish are primarily caught using otter trawls by vessels from Maine and Massachusetts (Mayo 2002; Sullivan et al 2017). Low fecundity and a slow growth rate has made Acadian Redfish vulnerable to overfishing in the past. Redfish have been exploited in New England since the 1930's.

The redfish fishery grew as freezing methods and transportation improved throughout the early and mid-1900's and peaked in 1952 at 130,000 metric tons. (Mayo et al 2002). Populations began declining in the Northwestern Atlantic during the 1950s. Regulations such as season and area closures, permit limits, gear restrictions, and minimum body size requirements were established in the 1990s. The population was recently considered rebuilt in 2012 (NFSC 2017).

A recent age structure and growth study suggests that population characteristics such as age, length at age, and age of maturity has not shifted in Gulf of Maine populations despite increased ocean temperatures and periods of overfishing (Sullivan et al 2017). However, more information is needed to assess this stock.

According to the 2017 stock assessment (NFSC 2017), Acadian redfish are not overfished and overfishing is not occurring. From 2012-2017, the average ex-vessel price of Acadian redfish has fluctuated between \$0.55/lb - \$0.67/lb (NMFS 2014; NMFS 2016; NMFS 2018).

Atlantic Pollock (Pollachius virens)

Overview

Atlantic pollock are part of the Gadidae family along with Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and white hake (*Urophyscus tenuis*). Atlantic pollock are found throughout the water column in the Northwestern Atlantic Ocean along the western Scotian Shelf, the Gulf of Maine, Great South Channel, and Georges Bank..They are common bycatch in the Acadian redfish fishery (Kanwit 2013, Pol 2015).

Atlantic Pollock reach maturity between 3 and 6 years old and will spawn multiple times per season. Preferred spawning habitat is hard, rocky, and cobble bottoms in cold water. Spawning occurs within a narrow range of temperatures between 4.5 - 8°C (Carnegelli et al. 1999). Timing of spawning differs by location. Spawning occurs in November through February in the Gulf of Maine and Georges Bank while spawning occurs September through April on the Scotian Shelf (Carnegelli et al. 1999). After eggs are released and fertilized, they rise into the water column. The free-floating eggs are found in water 50-250m deep (Hardy 1978) at temperatures ranging from 2-17°C. After 3-4 months as larvae, the small juveniles inshore inshore into rocky subtidal and intertidal zones. As they grow, juveniles make several inshore-offshore movements that correlate with temperature changes (Ojeda and Dearborn 1990; Rangeley and Kramer 1995;

Collette and Klein-MacPhee 2002). During summer, juveniles are found along inshore areas throughout New England and Long Island preferring temperatures between 4-12°C and depths between 25-75m. Adult pollock are distributed throughout the nearshore areas of the Gulf as well as offshore regions in the Gulf of Maine, Great South Channel, and along the northern edges of Georges Bank. Adults are associated with temperatures between 1-12°C while most were found in waters between 6-7°C from spring to fall. Research suggests that pollock segregate according to size with larger individuals inhabiting deeper waters (Steele 1963)

Atlantic pollock in the Scotian Shelf, Georges Bank, and the Gulf of Maine are assessed as single unit since there are no significant genetic differences among these fish (Mayo et al. 1989). Atlantic pollock are managed under the New England Fishery Management Council's Northeast Multispecies FMP. According to the 2017 stock assessment (NFSC 2017), Atlantic Pollock are not overfished and overfishing is not occurring. Overall, commercial landings have decreased every year from 2012-2016 from 6,742mt to 2,582mt. From 2012-2017, the average ex-vessel price of Atlantic pollock has fluctuated between $0.85/lb - $1.12/lb (NMFS 2014; NMFS 2016; NMFS 2018).

Butterfish (Peprilus triacanthus)

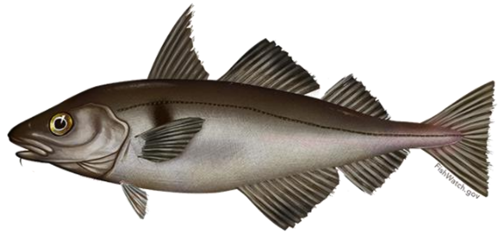
Overview

Butterfish are small, short-lived (~3 years), rapidly growing fish ranging from Newfoundland to Florida but are primarily found between Cape Hatteras and the Gulf of Maine. Butterfish feed on planktonic prey including small fishes, polychaetes, mollusks, crustaceans, and tunicates. The diet consists primarily of urochordates, ctenophores and marine gastropods (e.g., clione). They live near the surface, make seasonal migrations, and are considered eurythermal (4.4-22°C) (Fristz 1965; Schaefer 1967; Horn 1970) and euryhaline (5-32ppt) (Musick 1972). Butterfish have ecological importance as a forage fish serving as a valuable prey species for both small and large commercial fish such as haddock, silver hake, monkfish, bluefish, weakfish, and swordfish (Bigelow and Schroeder 1953; Scott and Tibbo 1968; Horn 1970; Brodziak 1995).

Butterfish mature during their second summer and broadcast spawners during June-July. Eggs and larvae are common in high salinity zones in Southern New England's estuaries, the Mid Atlantic Bight, and in Chesapeake Bay's mixing zone. Eggs have been found in the Gulf of Maine, on George's Bank, in the Mid Atlantic Bight, and off North Carolina. Butterfish begin schooling when they reach ~6 cm (Collette and Klein-MacPhee 2002).

Butterfish north of Cape Hatteras make seasonal migrations in response to changing temperatures. As temperatures warm, they move inshore and northwards from their wintering grounds on the edge of the Mid Atlantic Bight. Butterfish reach the Gulf of Maine in June and are most abundant in northern waters in September (MAFMC 1995). Butterfish begin moving southward from the Gulf of Maine in October. By January, butterfish move offshore to sandy, muddy, and rocky bottoms at depths of 200m in the Northwestern Atlantic and 350m in the South Atlantic Bight (Barans and Burrell 1976). Butterfish appear to distribute across different habitats by age-class in the spring, with age 2 and 3 fish found farther northeast and in deeper waters than age 1 butterfish (Adams 2017). Butterfish have also expanded their spatial distribution in association with increased surface temperatures (Adams 2017).

Butterfish are managed by the Mid-Atlantic Council. Overall, commercial landings have fluctuated interannually from 2012-2017 between 1,296mt - 3,871mt. From 2012-2017, the average ex-vessel price of butterfish has fluctuated between $0.54/lb-$0.66/lb (NMFS 2014; NMFS 2016; NMFS 2018).



Haddock (Melanogrammus aeglefinus)

Overview

Haddock are fast-growing, productive, and long-living fish that are part of the Gadidae family. They are slightly smaller than cod ranging from 0.2m – 1m and live in deeper waters from 25-75 fathoms. They are found from Newfoundland to New Jersey and are most abundant in Georges Bank and Gulf of Maine (Collette and Klein-MacPhee 2002).

Haddock feed on mollusks, worms, echinoderms and fish eggs. Juvenile haddock are an important prey item for other groundfish as well as skates, spiny dogfish, and gray seals (Collette and Klein-MacPhee 2002).

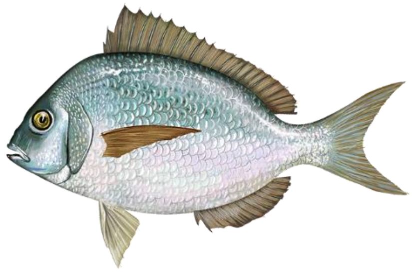
Haddock prefer bottom temperatures above 1.6 °C and below 11.1 °C at depths ranging from 45-135m. They prefer gravel, pebble, sand and broken ground substrates. The adult population in western Gulf of Maine conduct seasonal coastal movements (Collette and Klein-MacPhee 2002).

Haddock's age at maturity appears to have shifted earlier; in the late 1990's, about 75% of age 2 females were mature, while in the 1960's 75% of age 3 females were mature (O'Brien et al. 1993; Trippel et al. 1997). Haddock are broadcast spawners and there is a positive correlation between the size and number of eggs produced. Eggs are buoyant and cannot be distinguished from cod eggs. Spawning primarily occurs in Georges Bank from January to June (Brodziak et al. 2005). Peak spawning activity occurs when waters warm between February and early April. Hatching date and oceanographic conditions affect larval survival and growth - earlier hatchings appear to have an advantage over later spawned fish (Lapolla and Buckley 2005). Optimal temperature conditions for larval growth is 7-9°C. Conditions below 4°C are harmful (Laurence 1978)

Haddock in the Northwestern Atlantic are divided into three stocks - the Gulf of Maine stock, the Georges Bank stock, and Georges Bank East stock. The Gulf of Maine stock is jointly managed by NOAA Fisheries and the New England Fishery Management Council. Both entities collaborate with Canada to manage the Georges Bank stocks. Along with other groundfish, haddock is managed under the Northeast Multispecies FMP.

Assessments document that Georges Bank haddock has produced several exceptionally strong year classes in the last 15 years, leading to record high spawning stock and several large recruitment events in the Gulf of Maine since 2010. The population biomass is high, and the population is experiencing low mortality (NEFSC 2017)

Haddock are harvested with otter trawls, gillnets, as well as hook and line. According to the 2017 stock assessment (NEFSC 2017), haddock are not overfished, and overfishing is not occurring. Overall, commercial landings have increased every year from 2012-2016 from 1,970mt to 11,947mt. From 2012-2017, the average ex-vessel price of haddock has steadily decreased from $1.805/lb to $0.98/lb (NMFS 2014; NMFS 2016; NMFS 2018).



Scup (Stenotomus chrysops)

Overview

Scup are a long-living, slow growing, schooling species that are concentrated between Massachusetts and South Carolina but have been observed as far north as the Bay of Fundy (Scott and Scott 1988). Scup are found in estuaries and coastal waters during summer but migrate southward to the outer continental shelf at depths about 200m (Steimle 1999) in the winter. The Middle Atlantic Bight population mixes with the "southern porgy" (*S.aculeatus*) in the Middle/South Atlantic Bight area. They are managed by the Mid-Atlantic Council.

Smaller scup live in different environments and have different diets than larger scup (Smith and Norcross 1968). While scup have been documented to live to 20 years and reach sizes longer than 45cm (Bigelow and Schroeder 1953), most of the Middle Atlantic population is less than 7 years old and less than 33cm (Northeast Fisheries Science Center 1997). The average size of scup has been in decline since the 1930s (Smith and Norcross 1968).

Most scup are mature by age 3,and fork lengths of 21cm (Gabriel 1998). Maturation begins around age 2 at 15.5 cm. Spawning occurs from May through August along the inner continental shelf off southern New England in weedy and sandy areas (Fishwatch.gov). The buoyant eggs hatch in 2-3 days depending on temperature

(Griswold and McKenney 1984). Larvae feed on zooplankton in coastal waters during summer months. Juveniles and adults feed on benthic vertebrates in larger estuaries and in coastal areas during summer and early fall. Scup move southward to warmer waters during winter months from New Jersey to South Carolina (Steimle 1999).

Scup are commonly caught as bycatch during the spring/summer longfin inshore squid fishery in Southern New England and Nantucket Sound (Bayse et al. 2016). Commercial scup landings have fluctuated annually from 2012-2016 from 6,871mt to 8,166mt. From 2012-2017, the average ex-vessel price of scup has fluctuated between $0.55/lb - $0.71/lb (NMFS 2014; NMFS 2016; NMFS 2018).

Silver Hake (Mercluccius bilinearis)
Overview

Silver hake are fast growing, dense schooling, and fast-swimming semi-pelagic fish that are part of the Gadidae family. They are found over a wide range of temperatures and depths from Cape Fear, North Carolina to the Gulf of St. Lawrence and the Grand Banks of Newfoundland but are most abundant from New Jersey to Nova Scotia. They are managed by the New England Council under the Small Mesh Multispecies FMP (Lock and Packer 2004).

Because of morphometric differences and differences in fishing pressure, silver hake are managed as two separate stocks - a northern stock and a southern stock. The northern stock ranges from the Gulf of Maine to northern Georges Bank and the southern stock extends from southern Georges Bank to Cape Hatteras. The two stocks intermingle during the summer months on Georges Bank (Lock and Packer 2004).

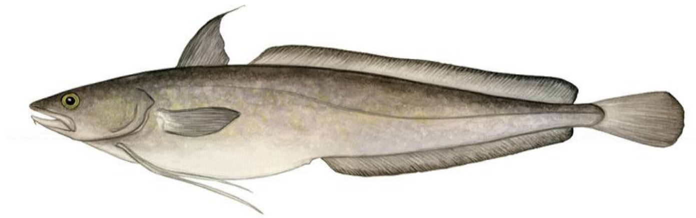
They are nocturnal feeders, preying primarily on fish (including other hake, mackerel, menhaden, alewives, and sandlance), crustaceans and squid (Garrison and Link 2000; Garrison 2002a). Feeding behavior is influenced by physical and temporal factors including stock, size, sex, season, migration, spawning, and age (Bowman 1984; Garrison and Link 2000; Rikhter et al. 2001). Cannibalism is common, especially among males (Link and Garrison 2002). Silver hake are an important prey item for Atlantic cod, white hake, red hake, and spotted hake. They are considered one of the most important prey species on Georges Bank for cod, skates, spiny dogfish, and harbor porpoises (Tsou and Collie 2001a).

Silver hake reach sexual maturity early around 2-3 years old. Spawning can begin as early as January in the Middle Atlantic Bight but most spawning activity occurs in shallow waters in spring and summer May-June in the southern stock and July - August in the northern stock (Brodziak 2001). Notable spring and summer spawning areas include coastal Gulf of Maine, southern and southeastern Georges Bank and southern New England (Lock and Packer 2004). Females are asynchronous, they can participate in up to 3 spawning events within one season. Eggs are found throughout the year off the New England shelf and in deep areas of Georges Bank (> 60m) (Steves and Cowen 2000).

Silver hake will migrate into deeper waters during autumn and into shallow waters during spring and summer to spawn. Water temperature influences the timing of migrations. Both adult and juvenile silver hake make diel vertical migrations - benthic by day and traveling throughout the water column by night following the diurnal vertical migration of zooplankton (Rikhter et al. 2001).

According to the 2017 stock assessment (NFSC 2017), silver hake are not overfished and overfishing is not occurring. Overall, commercial landings have fluctuated annually from 2012-2017 from 5352mt to 7390mt. From 2012-2017, the average ex-vessel price of silver hake has fluctuated between \$0.63/lb - \$0.76/lb (NMFS 2014; NMFS 2016; NMFS 2018).

Research by Sigaev 1992 shows that silver hake on the Scotian Shelf have lower recruitment in warmer temperatures. Muawksi 1993 suggests that distribution changes with temperature. Nye et al. 2011 found that the distribution shift was positively correlated to the position of the Gulf Stream.



White Hake (Urophycis tenuis)

Overview

White hake are found from the Gulf of St. Lawrence to the Middle Atlantic Bight in different environments including canyons, muddy basins, and estuaries (Chang et al. 1999). Although they are managed as a single stock under the Northeast Multispecies FMP, scientists discuss them as two; the northern stock and the Georges Bank – Mid Atlantic Bight stock. The northern stock spawns in the late summer in the southern Gulf of St. Lawrence and on the Scotian Shelf while the Georges Bank - Middle Atlantic Bight stock's spawning cycle and location are not well understood (Chang et al. 1999; Fahay and Able 1989).

White hake reach sexual maturity at different sizes in each stock. Males and females of the Gulf of St. Lawrence stock are mature when they reach 40cm and 43cm, respectively, while the Georges Bank- Middle Atlantic Bight stock's median age at sexual maturity is 1.5 years when males are 35cm and females are 32cm. Females grow larger and live longer than males. Demersal juveniles are found in eelgrass beds. Inshore demersal juveniles prefer depths 5-75m in the spring and 5 -50m in the fall while offshore juveniles can be found in deeper waters ranging from 50-225m in the spring and 5 -175m in the fall (Markle et al.1982; MacDonald et al. 1984; Heck et al.1989).

White hake make inshore movement during warmer months. They are most abundant inshore during spring and autumn when waters reach 5- 14°C (Markle and Frost

1985; Fahay and Able 1989; Chang 1990). Growth of adults is relatively slow and spawning occurs in a relatively narrow time span (early spring) in deep water (Chang et al. 1999).

White hake are cannibalistic; adults also feed on fish and crustaceans while juveniles feed on polychaetes and crustaceans (Bowman 1981; Langton et al 1994). White hake are an important prey species for coastal seabirds in Maine including Atlantic puffins and Arctic terns (Fahey and Able 1989; Hall et al 2000; Kress et al 2016; Yakola 2019**).**

White hake are both incidentally and directly caught. According to the 2017 stock assessment (NFSC 2017), white hake are not overfished and overfishing is not occurring. Overall, commercial landings have fluctuated annually from 2012-2017 from 3029mt to 6129mt. From 2012-2017, the average ex-vessel price of silver hake has fluctuated between $1.02/lb - $1.38/lb (NMFS 2014; NMFS 2016; NMFS 2018).

Wood et al 2008 shows that the decrease in white hake abundance in Narragansett Bay is correlated with warming ocean temperatures. Morley et al 2018 suggests the centroid of the stock is expected to shift poleward.

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